# GUIDE TO SEDIMENTATION INVESTIGATIONS

## SOUTH REGIONAL TECHNICAL SERVICE AREA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING AND WATERSHED PLANNING UNIT
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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

# INTRODUCTION

This guide has been prepared by the Engineering and Watershed Planning Unit at Fort Worth, Texas, for use by watershed work plan staff geologists in making sedimentation investigations.

The material presented herein is supplemental to Washington technical memoranda, and provides details that are not included in such memoranda. Its loose-leaf form allows for the insertion of future changes and revisions.

It is not intended as a guide to replace existing State memoranda or guides, but is an attempt to assemble all material on sedimentation investigations into one manual.

Sedimentation investigations have a wide range of purposes. The primary purposes and scope of these investigations are to determine:

1. Physical conditions which influence erosion, entrainment, transportation, and deposition of sediment.
2. The extent and degree of erosion and sedimentation damages to agricultural lands, reservoirs, roads, bridges, channels, irrigation and drainage ditches, municipal water supplies, and other rural and urban property.
3. Critical sediment-source areas in respect to damages.
4. The land treatment, land stabilization, and structural measures needed to reduce sediment and erosion damages, and the effects of proposed measures.
5. Storage requirements for accumulation of sediment in floodwater retarding and other water-impounding structures.
6. The effects of changes in stream regimen on channel stability.

# CHAPTER I

## ASSEMBLY AND REVIEW OF ALL AVAILABLE SEDIMENTATION AND GEOLOGIC DATA

Geologic and sedimentation investigations should begin with an assembly and review of all available basic data pertaining or applicable to the watershed under study. Other agencies, both Federal and State, have made various types of sedimentation studies. These should be reviewed in an attempt to make Service investigations broader and more complete. A number of sources can be utilized to obtain this information. Some of these are listed below, but others may exist. All possible sources of such information should be explored to the fullest possible extent.

1. Geological survey reports and maps.
2. Soil survey reports and maps.
3. Land Resource Area maps.
4. Land Capability Guides.
5. Soil conservation district work plans and conservation needs data.
6. Reservoir sedimentation survey and/or suspended sediment load data for or applicable to the watershed area.
7. Sedimentation data from flood control survey reports, field examinations, special storm reports, etc.
8. Geological maps and reports of major oil companies.

# CHAPTER II

## RECONNAISSANCE INVESTIGATIONS OF WATERSHEDS TO DETERMINE LOCATION, EXTENT, AND SEVERITY OF SEDIMENTATION AND GEOLOGIC PROBLEMS

A thorough reconnaissance of the watershed should be made by the work plan staff geologist before any conclusions are drawn pertaining to the solution of sedimentation problems. Of particular concern to the geologist during this reconnaissance are the following:

1. General geology, soils, topography, land use, cover, and hydrophysical conditions as related to:
   a. Erosion.
   b. Transportation of sediment.
   c. Deposition of sediment.
2. General nature and extent of sediment and erosion damages:
   a. Sediment deposition on upland areas.
   b. Sediment deposition on flood plains.
   c. Sediment deposition in reservoirs and ponds.
   d. Sediment deposition in stream channels.
   e. Sediment deposition in irrigation canals and drainage ditches.
   f. Swamping or high water table.
   g. Flood plain scour.
   h. Streambank erosion.
   i. Valley trenching

3. Relative importance of damaging sediment sources.

   a. Sheet erosion.

   b. Gully erosion. Valley side gullies

   c. Streambank erosion.

   d. Valley trenching. Valley head gullies (Brice)
      Valley bottom

   e. Flood plain scour.

   f. Other - wind, road, mine wastes, etc.

   g. Critical sediment-source areas.

4. Location of reservoirs and ponds.

   A tentative selection should be made of any existing reservoirs or ponds for possible sedimentation surveys, if reliable basic data for estimating sediment yields are not available for the watershed. The reservoirs or ponds should be selected to represent specific problems encountered in the field and should meet the following requirements:

   a. Drainage area of 1/10 square mile to 20 square miles.

   b. Should be at least 5 years old, preferably older.

   c. Should not have failed or had sediment removed.

   d. Upstream ponds do not control an appreciable portion of the total sediment yield.

5. Land damage by waste or pollutants from industries, sewage disposal, abandoned wells, oilfield waste, acids, detergents, etc., and natural outflow of salt or alkali from springs or other sources.

# CHAPTER III

## PREPARATION OF SEDIMENTATION AND GEOLOGIC PARTS OF THE WORK OUTLINE

Based on the erosion and sedimentation characteristics of the watershed, as determined during the reconnaissance investigation, a thorough analysis of the jobs to be done and the time required for each should be made. To insure orderly development of the work plan, man-days required for each phase of the investigation, as well as goal dates, should be carefully coordinated with the activities of all other specialists on the work plan staff.

4-19870

# CHAPTER IV

## PREPARATION OF WATERSHED GEOLOGIC MAP

The work plan staff geologist should prepare a geologic map of the surface features in a watershed. Knowledge obtained in his review of published information and maps, coupled with knowledge gained during the reconnaissance, will enable the geologist to prepare this map. It can be used during the early stages of work plan development in selecting representative conditions for detailed study. It also will be useful in the operations stage by providing the geologist a broader view of watershed conditions.

# CHAPTER V

## SELECTION OF VALLEY CROSS SECTIONS OR SAMPLE MAPPING AREAS

Where possible the work plan staff geologist should collaborate with other members of the work plan staff in the selection of the best locations for valley cross sections or sample mapping areas.

For sedimentation purposes, the cross sections selected should reflect average valley conditions throughout the flood plain. Field inspection of the alluvial valleys in the watershed will indicate the extent of the necessary range or cross-section system. In general the ranges should extend transversely to the main axis of the valley and should be located so as to provide a representative sample of the area. They should be spaced at intervals not exceeding two to four times the width of the flood plain. For example, if the flood plain has an average width of one-half mile, a recommended interval between cross sections would be one to two miles. Closer spacing is necessary if identification of old soil profiles is difficult or if the modern deposit is highly irregular in thickness or extent.

If deposition areas are sparse and widely scattered, areal mapping of selected sample areas or reaches should be employed rather than using the cross sections.

# CHAPTER VI

## SOIL-COVER COMPLEX INVESTIGATION

The geologist and hydrologist usually collaborate in developing the soil-cover complex field investigations. These investigations are made in consultation with the area and/or work unit conservationist and the area soil scientist.

The data developed by the geologist in making detailed sediment-source studies are used in computing the soil-cover complex values. Procedures for developing the soil-cover complex are contained in Section 4, National Engineering Handbook, Part I - Watershed Planning, chapters 7, 8, and 9.

The Forest Service is expected to provide soil-cover complex data for woodland areas.

# CHAPTER VII

## INVESTIGATIONS AND COMPUTATIONS TO DETERMINE GROSS EROSION AND SEDIMENT YIELD

Gross erosion should be computed separately from each source.

The major sediment sources considered herein are: Sheet erosion, gully erosion, roadside erosion, and streambank erosion.

### Sheet Erosion

Sheet erosion is computed by the Musgrave equation:

$$E = FR \left(\frac{S}{10}\right)^{1.35} \left(\frac{L}{72.6}\right)^{.35} \left(\frac{P_{30}}{1.375}\right)^{1.75}$$

where

E = Sheet erosion, tons per acre per year

F = Soil factor, basic erosion rate in tons per acre per year for each soil series or unit (Table 1)

R = Cover factor (Table 2 or 3)

L = Length of land slope in feet (Table 4)

$P_{30}$ = Maximum 30-minute, 2-year frequency rainfall, in inches (Figure 1)

Sheet erosion also can be computed by a modification of the Musgrave equation: 1/

$$E = KCR \left(\frac{S}{10}\right)^{1.35} \left(\frac{L}{72.6}\right)^{.35}$$

where

E = Sheet erosion, tons per year

K = Erosion rate, soil factor, tons per acre per year per unit of rainfall index for each soil series (Table 1a)

R= C = Cover factor (Table 2 or 3)

1/ This modified Musgrave equation is developed by substituting the "K" factor and rainfall index from the ARS Universal Erosion Equation (See footnote 1, next page) for the "F" factor and rainfall adjustment factor in the Musgrave equation.

4-19870

R = Rainfall factor, rainfall erosion indices (Figure 1a)

S = Land slope in percent (Table 4)

L = Length of slope in feet (Table 4)

To illustrate these methods for computing annual sheet erosion, step by step, tabulations and computations for a sample watershed are shown in Table 5.

Table 1a and figure 1a are included for use with the Modified Musgrave equation. Table 1a is a list of the Soil Series and K factors (erosion rates) in the South Region. Figure 1a is a map of the South Region showing Iso-Erodent factors. These data are used in the Universal erosion equation developed by the Agricultural Research Service. 1/ The K factors from table 1b can be substituted for the Basic Erosion Rates in table 1. The Iso-Erodent factor on Figure 1a can be substituted for the rainfall adjustment factor in Figure 1. With these substitutions, the geologist can compute soil loss using the other factors in the Musgrave equation as he has in the past. This procedure will allow the geologist to use Soil Series data direct rather than converting soil series to soil units. The universal erosion equation has not yet been adapted for use in watershed evaluation in its entirety because its application has been confined as a working tool for recommending conservation measures on cultivated land. Therefore the Musgrave, or the modified Musgrave, equation is recommended for watershed work.

Assuming that a soils map of the watershed is available, the first step in computing annual sheet erosion is to delineate and/or measure the area (acres) of each type of cultivated crop (small grains, row crops, etc.) and/or

1/ Rainfall-Erosion losses from cropland East of the Rocky Mountains. Agriculture Handbook No. 282, Agricultural Research Service, USDA, dated May 1965.

range, pasture or woodland condition class by soil series or unit, land slope in percent, length of slope in feet and type of treatment (such as terraced areas). Total all like delineations or measurements and record under basic data on a form such as Table 5.

From Table 1 or 1a select the basic erosion rate 1/ by soil series or unit and record it in column 18. From tables 2 or 3 and 4 and figure 1 or 1a, select the sheet erosion adjustment factor for each separate tabulation and record in the appropriate column. The product of columns 17, 18, 19, 21, and 23 is the average annual sheet erosion in tons for present conditions (column 24).

All data used in Table 5 are self-explanatory except slope length. Slope length may be measured on aerial photographs or on the ground. On terraced fields slope length is the average distance between terraces. For all other areas slope length is the total uninterrupted distance overland flow must travel, on a given grade, before reaching a well-defined drainageway. Fence rows across slopes are considered as slope length breaks. In some cases slope length may not be confined entirely to the field or farm involved, but may include the distance across a neighboring area.

The computation for future conditions, after the installation of land treatment, is made by entering the proper data under the future columns on Table 5. The computations are then made as they were for present conditions. The product of columns 17, 18, 20, 22 and 23 is the average annual sheet erosion in tons for future conditions (column 25).

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1/ Basic erosion rate values in Table 1 are based on 10 percent land slope, 72.6 ft. slope length, 100 percent row crop cover cultivated downhill, and a 30-minute, 2-year frequency rainfall of 1.375". Tables 2, 3, and 4 are used to adjust for any change from the above conditions.

Roadside, Gully and/or Streambank Erosion

Annual erosion (tons) from these sources is computed from measurements made in the field and recorded on a form similar to Table 6. In connection with column 6 of this table, annual rates of lateral or vertical cutting can be estimated by comparing aerial photographs of different dates, from cross-section resurveys, data from land operator or other local residents. To illustrate this procedure for computing annual streambank and gully erosion, the tabulations and computations for a sample watershed are shown on Table 6.

Table 1

BASIC EROSION RATES BY SOIL UNITS

| Soil Unit 1/ | Volume Weight (lbs./cu.ft.) 2/ (Top Soil) | Basic Erosion Rates (Annual) Inches 3/ | Tons/Ac. | Land Resource Area 4/ |
|---|---|---|---|---|
| 1 | 82.0 | 0.65 | 97 | All |
| 2 | 81.0 | 0.54 | 79 | " |
| 2X | 84.0 | 0.41 | 63 | " |
| 2Xd | 84.0 | 0.08 | 12 | " |
| 3 | 82.0 | 0.65 | 97 | " |
| 4 | 81.0 | 0.54 | 79 | " |
| 4H | 81.0 | 0.54 | 79 | " |
| 4X | 84.0 | 0.41 | 63 | " |
| 5 | 98.0 | 0.65 | 116 | All except 132, 134 |
| 5a | 98.0 | 0.65 | 116 | " " " " |
| 5 | 86.0 | 0.65 | 101 | 132, 134 only |
| 5a | 86.0 | 0.65 | 101 | " " " |
| 6 | 95.0 | 0.41 | 71 | All except 132, 134, 78, 80, 84 |
| 6 | 88.0 | 0.65 | 104 | 132, 134 only |
| 6 | 95.0 | 0.54 | 93 | 78, 80, 84 only |
| 7 | 95.0 | 0.29 | 50 | All except 116, 117, 84, 132, 134 |
| 7 | 95.0 | 0.41 | 71 | 116, 117, 84 only |
| 7 | 95.0 | 0.41 | 71 | 116, 117, 84 only |
| 7 | 88.0 | 0.65 | 104 | 132, 134 only |
| 7d | 88.0 | 0.15 | 24 | All |
| 7f | 88.0 | 0.15 | 24 | " |
| 7X | 90.0 | 0.15 | 24 | " |
| 7Xd | 90.0 | 0.08 | 13 | " |
| 70 | 95.0 | 0.15 | 26 | " |
| 8 | 91.0 | 0.41 | 68 | " |
| 9 | 96.0 | 0.29 | 51 | " |
| 10 | 98.0 | 0.29 | 52 | " |
| 11 | 98.0 | 0.29 | 52 | " |
| 12 | 98.0 | 0.15 | 27 | " |
| 12X | 98.0 | 0.12 | 21 | " |
| 13 | 98.0 | 0.12 | 21 | " |
| 14 | 98.0 | 0.29 | 52 | " |
| 15 | 98.0 | 0.12 | 21 | " |
| 16 | 82.0 | 0.65 | 97 | " |
| 17 | 81.0 | 0.54 | 79 | " |
| 18 | 84.0 | 0.41 | 63 | All except 84 |
| 18 | 84.0 | 0.65 | 99 | 84 only |
| 18d | 84.0 | 0.15 | 23 | All |
| 18c | 85.0 | 0.08 | 12 | " |
| 19 | 86.0 | 0.65 | 101 | " |
| 20 | 87.0 | 0.41 | 65 | " |
| 20d | 87.0 | 0.15 | 24 | " |

Table 1 (Continued)

BASIC EROSION RATES BY SOIL UNITS

| Soil Unit 1/ | Volume Weight (lbs./cu.ft.) 2/ (Top Soil) | Basic Erosion Rates (Annual) Inches 3/ | Tons/Ac. | Land Resource Area 4/ |
|---|---|---|---|---|
| 23 | 90.0 | 0.41 | 67 | All |
| 24 | 81.0 | 0.54 | 79 | All except 133 |
| 24 | 81.0 | 0.65 | 96 | 133 only |
| 24d | 81.0 | 0.41 | 60 | All |
| 24c | 82.0 | 0.08 | 12 | " |
| 25 | 95.0 | 0.41 | 71 | All except 132, 134, 133 |
| 25 | 95.0 | 0.65 | 112 | 132, 134, 133 only |
| 25c | 96.0 | 0.08 | 14 | All |
| 25d | 95.0 | 0.08 | 14 | " |
| 26 | 98.0 | 0.08 | 14 | " |
| 27 | | 0.08 | | All except 132, 134 |
| 27 | | 0.65 | | 132, 134 only |
| 28 | | 0.08 | | All except 78, 80 |
| 28 | | 0.65 | | 78, 80 only |

1/ Standard definitions attached (Table 1a). (Soil series descriptions can be used to classify soil series into the above units.)

2/ Based on all available volume weight data.

3/ Source data - Table III, Soil Conservation Surveys Division Memo on Conservation Time Table Study, dated 26 April 1949 to State Soil Scientists and Survey Supervisors.

4/ See Figure 4.

Table 1a. Soil Series, K Factor Values, 1/ of the South RTSC States as of November 1, 1963

Aberdeen sil .37
Aberdeen sicl .37
Abilene cl .37
Abilene sicl .43
Acadia sil .43
Acme cl .32
Adair sicl .43
Agar sicl, sil .32
Agnos gr fsl .28
Agnos loam .32
Agnos lfs .24
Agnos gr lfs .20
Akaska sil, sicl .28
Alamance .37
Albertville .37
Albion sl .20
Alcester sil .28
Alcester sicl .32
Alcoa .30
Algiers .37
Allegheny fsl .28
Allegheny sl .32
Allen .32
Altavista .32
Alto .32
Altus fsl .28
Altus lfs .24
Altvan .32
Amarillo fsl .28
Amarillo lfs .24
Amarillo l .32
Americus ls .17
Americus .17
Amite .28
Anacoco .49
Anacoco, th sur. .43
Angie .28
Anniston .32
Anselmo fsl .20
Anselmo l .24
Anthony fsl .20
Apache stony cl .32
Apison .37
Appling .37
Arch l .32
Armour sl .32
Armour ch sl .28
Armuchee .43
Arnegard l, sicl .32
Arnegard sil .28
Arvana l .32
Arvana fsl .28
Arvana lfs .24
Arvonia .37
Arzell .17
Ascalon sl .20
Ascalon l .24
Ashburn .32
Ashburn sil .28
Ashe, mod. sh .24
Ashe sh .32
Ashton sl .28
Ashton ch sl .24
Ashwood rocky sl .32
Assaria sil .43
Athol .32
Atlee .37
Atwood .32
Augusta .43
Austin sic .43
Avery .32
Avonburg .43
Axtell fsl .49

Bainville l .37
Balfour .32
Banquete c .43
Banks ls .17
Banks s .15
Banks sl, l .20
Barbourville .28
Barbourville gr .28
Barnes cl .37
Barnes l, sil .32
Barth .20
Bastrop fsl .28
Bates fsl .24
Bates l .28
Bates sil .32
Baxter sil .37
Baxter, ch .32
Bayard fsl .20
Beadle cl .37
Beadle sil .32
Bearden sicl .32
Bearden sil .28
Beasley .43
Beasley, ch .37
Beaumont c .43
Beauregard .28
Beaverton l .24
Beaverton sl .20
Bedford .43
Belfore sicl .37
Bell c .43
Beltsville .43
Benfield sil .43
Beotia sil .28
Beotia sicl .32
Berg sil .37
Berks, mod dp .28
Berks shaly .24
Bernard cl .43
Berthoud fsl .20
Berthoud l .24
Berthoud sicl .32
Berthoud sil .28
Bertie .43
Bethany sil, cl .37
Beulah ls .17
Beulah sl .20
Bewleyville .37
Bexar .43
Bienville .24
Bigbone .37
Binnsville .49
Bippus cl .32
Bippus fsl .28
Blakely l .32
Blago .37
Blanco sil .28
Bland .43
Blanket cl .37
Blanton s .17
Bloomington sil .28
Bodine ch sil .24
Bolton .34
Bonham cl .37
Bonilla l .32
Bonilla l, sicl .32
Bonilla sil .28
Bonnacord sil .43
Bonti fsl .24
Bosket sil .32
Bosket sl .28
Boswell fsl .43
Bottineau l, cl .37
Bowie fsl .28
Bowie lfs .37
Boyd sicl .37
Boyd sicl, c .49
Brackett cl .43
Braddock gr l .24
Bradley .37
Brandon sil .37
Brandon gr sil .32
Brandywine mod dp .24
Brandywine sh .24
Brantford sl .24
Brashear .37
Braxton .32
Braxton, ch .32
Brays .37
Brazos lfs .17
Brecknock .24
Bremo .32
Brennan fsl .28
Brennan lfs .24
Brewer sicl .49
Brewster Stony l .28
Bridgeport cl .32
Bridgeport sil .28
Brooke .43
Brookings sicl .32
Brooksville .49
Brownfield fs .17
Brownfield lsf .24
Bruno ls, lfs .17
Bub stony sl .28
Buckingham .28
Buckingham, very stony .20
Buckingham, very gravelly .17
Bucks .32
Bude .43
Buffington sicl .37
Burchard cl .37
Burleson c .43
Burton .24
Buse l .32
Butler sicl, sil .43
Buxton .43
Byars .43

Byington .43

Caddo .28
Caddo sil .43
Cady fsl, sl .20
Cahaba fsl .28
Cahaba, th sur .20
Calloway .43
Calverton .32
Calvin sil, mod. dp. .28
Calvin shaly sil .24
Cameron sic .37
Camp .32
Canadian fsl .20
Canadian l .24
Cane .43
Caneyville .43
Canyon l .28
Capshaw .43
Captina sil .43
Captina ch sil .37
Carbo .43
Carey fsl, l .28
Carmen fsl .28
Carnero l .43
Carnegie .32
Carytown .43
Caroline .43
Cass fsl, l .28
Catoctin .32
Catoctin, sh .32
Cataula .43
Catlett .28
Cavode .43
Cavour, l .32
Caylor l .32
Cecil .37
Center .37
Chama l .32
Chama, vf sl .32
Chandler, mod. dp. .32
Chandler, sh .32
Chappell, l .32
Chase sicl .37
Chattahoochee .32
Cherokee sil .49
Cherry sicl .37
Chester sil .32
Chesterfield l .37
Cheyenne sil, l .24
Chickasha fsl, l .24
Chigley sl .32
Chilhowie .32
Choctaw .43
Choteau fsl .32
Christian fsl, sil .37
Christian gr. lfs .28
Christian, ch. .32
Church cl .37
Cincinnatti .37
Claiborne .32
Clareville l .32
Clark cl .37
Clarksville, ch. .24
Claremore sil .32
Clifton .32
Cloud sicl .43
Clymer .28
Clymer fsl .24
Cobb fsl, sl .24
Coeburn .28
Colbert .43
Colby sil .28
Colfax .37
Colleen .37
Collinsville l .24
Conasauga .43
Conroe lfs .20
Conway fsl .43
Cookeville .37
Cookport .37
Corson sic .43
Corydon .43
Cotaco .28
Cotaco gr l .28
Cottonwood l .24
Coxville .42
Craig sil .43
Craven .43
Crawford c .43
Creedmoor .43
Cresbard sil, l .32
Crete sicl .43
Crider .37
Crockett fsl .43
Crofton sil .32

Crossville .24
Croton .43
Crowley .43
Cruze .32
Cuero cl .37
Cuero fsl .28
Culleoka .28
Culpeper .37
Cumberland .32
Cushman l .32
Cuthbert sl, fsl .43
Dalhart l .32
Dalhart fsl .28
Dalhart lfs .20
Dandridge .24
Darnell fsl .24
Davidson .32
Dawes sic, sicl .43
Dawes sil .28
Decatur .32
Dekalb sl, fsl .24
Dekalb channery sl .17
Dale sil, cl .32
Dellrose .20
Delmita fsl .24
Dennis l, sil .37
Denton c .37
Detroit sil .37
Dewey .32
Dexter .37
Dickey l .24
Dickey sl .20
Dickson sil .43
Dickson ch sil .37
Dickinson fs .24
Dierks .20
Dill lfs .24
Dix sl .15
Doland sil .28
Donerail .37
Dougherty fsl .28
Dougherty lfs .24
Dowellton .49
Dragston .28
Drake l .32
Dubbs sil .32
Dubbs sl .28
Duffield .32
Dulac .43
Dunbar .37
Dunday ls .17
Dundee sl .32
Dundee sil .37
Dundee sicl .43
Dunlap sicl .32
Dunlap sil .28
Dunmore .43
Duplin .37
Durant cl .43
Durham .32
Duval fsl .24
Duval lfs .17
Dwight sil .49
Dwyer ls .17
Dyke .37

Eakin sil .32
Ebenezer sicl .43
Eckman l .24
Eckman sil .28
Ector stony l .28
Edalgo sil .43
Eddy gr l .32
Eden .43
Edenton .37
Edge fsl .49
Edgemont .24
Edgley l, cl .32
Edna l .43
Edneyville .28
Edom .28
Efland .43
Egeland fsl, l .20
Elbert .49
Eldon ch sil .32
Eldorado ch sil .32
Elioak .32
Elk .32
Elkader sil .28
Elkton .43
Elliber ch .24
Elliber very ch .17
Ellis c .43
Elmo sil .37
Embden fsl .20
Emory .28

Enders .37
Engle scl .28
Englund sil .43
Enon .43
Enterprise fsl .20
Enterprise vfsl .24
Epping sil .28
Eran cl .43
Estelline sil .28
Esto sl .43
Etowah .32
Eubanks .37
Eufaula fs .15
Eufaula s .17
Eulonia .28
Eustis lfs .17
Eustis s .17
Eutaw .49
Ewing sicl .43

Faceville fsl .32
Fairdale l .32
Fairhope fsl .43
Fairfax .43
Fairmount, flaggy .43
Falkner sil .49
Falun fsl .28
Fannin .43
Fargo c .43
Farland l .32
Farland sic .49
Farnum fsl .32
Farragut .37
Fauquier .32
Fayette .37
Fayetteville fsl .2
Fayetteville lfs .20
Fitzhugh fsl .24
Flandreau l, sl .32
Flasher ls .17
Flasher sl .20
Fletcher .37
Flemming .37
Flint .43
Florence ch sil .24
Fluvanna .37
Foard sil, cl .49
Fordville l .28
Fordville l, dp. .2
Forman l .37
Frankstown sl .32
Frankstown, ch sil .28
Frederick sil .32
Frederick, ch sil .28
Freeland sil l .37
Freeland sl .37
Frio sicl .32
Fullerton sil l .32
Fullerton ch sil .2

Galestown ls .17
Galestown s .17
Fainesville lfs .17
Gardena l, sil .28
Gann, sil .28
Gascomade .49
Geary sil .32
Geary sicl .37
Geiger .43
Georgeville .37
Gerald sil .43
Gilead, lfs th sur. .28
Gilead sl .37
Gilpin sil l .32
Gilpin shaly sil .24
Glenelg .32
Glenville .32
Goessel c .49
Goldsboro .28
Goldston .43
Goliad cl fsl .32
Gomez lfs .17
Gomez fs .15
Gore .49
Goshen l sil .32
Grail sicl .37
Grail sil .32
Grant l .28
Granville .28
Great Bend sicl .37
Greendale .28
Greenville fsl sil l .32
Grenada .43
Groseclose .43
Groveland sl .20
Grover .37

1/ Rainfall-Erosion Losses From Cropland East of the Rocky Mountains. Agri. Handbook No. 282, ARS-USDA, May 1965.

Table 1a Continued

Grundy sicl .37
Guin l .17

Habersham .28
Habersham, channery .24
Hagerston .32
Halewood .32
Halewood, sh .32
Hall, sil .32
Hallville l .28
Hamerly l .28
Hampshire .42
Hampshire, sh. .38
Harbin fsl .28
Hanceville .28
Harlingen c .32
Harney sil .37
Harley fsl lfs .43
Hartsells fsl .24
Hartsells, silt loam .28
Hastings sil .37
Hatchie .37
Haxtun fsl .20
Hayesville .37
Hayter .28
Hazel .32
Hecla fsl sl l .20
Hecla ls lfs fs .17
Hector fsl .32
Hedville fsl .20
Heitt .37
Helena .43
Henderson ch sl .32
Henshaw .37
Hensley l .32
Hermitage .32
Herndon .37
Hicks .37
Hidalgo fsl scl .28
Hiwassee .32
Hobbs cl sil .32
Hockley fsl .28
Hoffman .43
Holdrege sil .32
Hollister cl .43
Hollywood .49
Holston fsl .28
Holston sil .32
Holt sil .28
Holt sl l .24
Hooten .42
Hord sil .32
Hortman .43
Houdek l sil .32
Houston c .43
Houston black c .43
Huckabee ls .20
Huckabee s .17
Huff l .32
Huggins l .32
Huggins sl .28
Humphreys .32
Humphreys ch sil l .28
Hunt c .43
Hyattsville .28

Ida sil .32
Idana sil .37
Index .37
Inman .43
Inola sil .43
Iola gr. l .20
Iredell .49
Irvington .28
Irwin sicl .43
Izagora fsl .43

Janise sicl .43
Jefferson .28
Jessup sil .37
Joe Creek sil .32
Johnsburg .43
Judson sil .32

Kadoka sicl .32
Kalmia fsl .28
Kalmia lfs th. sur. .20
Kanapaha fs .17
Katy fsl .43
Kaufman c .32
Kaw sil .32
Keith sil .32
Kelvin l, sicl .37
Kempsville .28
Kempsville, th sur .20
Kempsville, heavy sub. .28
Kenansville .20
Kenesaw sil .28
Kennebec sil .28
Kenny lfs .17
Kenton sil .43
Keota sil .28
Kershaw .17
Keyport .43
Killian ls .37
Killian s .28
Kimbrough l .32
Kingfisher sil .32
Kipling .43
Kipp sil .37
Kipson sil .24
Kirkland sil cl .49
Kirvin fsl .43
Kisatchie .49
Klej, sand .17
Klej ls .17
Knippa c .37
Kranzburg l, sicl, sil .32
Krum c .37
Labette cl .37
LaCasa cl .37
LaDelle l, sicl .32
Ladoga sil .43
Ladysmith sicl .43
Lafe sil .49
Laidig .28
Lake Charles c .37
Lakeland lfs ls .20
Lakeland s .17
Lakewood .17
Lakin lfs .17
Lakin s .17
Lamar cl .37
Lane c, sic .43
Lane l, sicl .37
Lancaster l .37
Landisburg .43
Landisburg, ch. .32
Langley sil .37
Lanham sic, c .49
Lansdale .28
LaPrairie sil .32
Laredo sicl .32
Lauderdale, stony sl .32
Lawrence .43
Lax .37
Lea l .32
Lea fsl .28
Leadvale .43
Leaf .43
Lebanon .43
Letonia .24
Letonia, stony .17
Lefor fsl .28
Legore .24
Lehew, sil .32
Lehew, shaly .24
Lehigh .43
Lenoir .43
Lexington .37
Lewisville c .37
Lickdale .43
Licking sil .37
Lignum .37
Lihen fsl .20
Lihen lfs, ls .17
Liking sil, sicl .37
Likes lfs .17
Lindy l .32
Linker fsl .28
Lismas c .49
Lismore sic .32
Litz sil .32
Litz, shaly .24
Lloyd .32
Lockhard sil .43
Lockhart .37
Locust fsl .43
Lodi .43
Lofton cl .43
Longford sil .37
Loradale .37
Loring .37
Louisa .37
Louisburg .32
Lozier gr. l .24
Lowell .37
Lubbock cl .37
Lubbock fsl .28
Lucien fsl .24
Lufkin fsl 49
Lunt .49
Luverne .37
Lynchburg .28

Macon .43
Maddock fsl, sl .20
Maddock ls, lfs .17
Madison .37
Magnolia .32
Makoti sicl .37
Malcolm sil .32
Malt .32
Manassas .32
Mangum .43
Manor .28
Manor, micaceous .43
Manse .28
Mansic l, cl .28
Mansker l, cl .28
Mansker fsl .24
Manteo .37
Manter fsl .24
Markland .49
Marlboro .32
Marshall sil .32
Marydell sil .37
Masada .34
Matapeake .32
Matapex .37
Matney .32
Maury .32
May fsl .28
Mayhew .42
Mayodan .37
McAfee .37
McKamie .43
McLain l, cl, sil .32
McPherson sil .43
Mecklenburg .43
Memphis .37
Mercer .43
Mereta cl .32
Miguel fsl .43
Miguel lfs .43
Miles fsl .28
Miles l .32
Miles lfs .24
Miller cl .32
Mimosa .43
Minco fsl .20
Minco sil .28
Minco vfsl, l .24
Minnequa sil .28
Minvale .32
Minvale, ch. sil .28
Mitchell sil .32
Mobley .43
Molena .20
Moline l, cl .49
Mondamin sicl .43
Mondamin sil .32
Monona sil .32
Monongahela .43
Montalto .32
Monteola c .32
Montevallo sil .32
Montevallo, shaly .28
Moody sicl .32
Moody sil .28
Moreau sic .49
Moro Bay .43
Morrill l .37
Morse c .49
Morton l, sil .32
Mountview .37
Muir sil .32
Murrill .28
Muse .32
Muskingum .28
Muskogee sil, fsl .43
Myersville .32

Nacogdoches cl .37
Naron fsl .24
Nash l, sil .24
Nason .37
Natchez .37
Natchitoches .49
Navasota cl .32
Needmore .43
Negley .32
Neosho sil .49
Neubert .28
Newtonia sil .32
Nicholson .32
Niles sil .43
Nimrod fs .18
Nimrod lfs .20
Nixa .43
Nixonton .32
Noble l, fsl .24
Nobscott fs .15
Nolichucky .28
Nora sil .28
Norfolk fsl .28
Norfold lfs .24
Norfolk, th. sur. .20
Norge fsl .32
Norge l .28
Norwood scl .32
Norwood fsl .24
Nuckolls sicl .37
Nuckolls sil .32
Nutley sicl, sic, c .43

Oahe l, sil .24
Oahe sl .20
Oak Lake sil, sicl .32
Okemah sicl .43
Oktibbeha .43
Oldham sicl .43
Olton l .37
O'Neill fsl .24
Ora .32
Orange .49
Orangeburg .28
Orangeburg ls .24
Orangeburg, th. sur. .20
Orelia fsl .43
Orella sic, c .49
Orman c, sic .49
Orman sicl, sil .43
Ortello sl .20
Ost cl .37
Otero fsl .20
Otero lfs .17
Otway .49
Overly sicl .32
Owens c .43

Pace sil .32
Pace, ch .28
Paden .43
Paralona .20
Parshall fsl, sl .20
Parshall l, sil .24
Parshall ls .17
Parsons sil .49
Patent l .37
Patoutville .43
Patrick sic .37
Pawnee c .49
Pawnee cl, sicl .47
Payne cl .43
Pearman .43
Pederales l .43
Pembroke .32
Penn sil .32
Penn, sh .24
Perkinsville .28
Perry cl .32
Pheba .37
Pickaway .43
Pickwick .32
Pierre c .49
Pierre cl .43
Piney .43
Pinkston .49
Pisgah .28
Plummer fs .17
Poinsett sicl .32
Poinsett sil .28
Pond Creek sil .32
Pontotoc fsl .28
Portales fsl .28
Portales l, cl .32
Porters .24
Portland c .32
Potter l .32
Pottsville, gr. fsl .28
Pratt fsl .20
Pratt lfs .17
Prentiss .37
Prescott .32
Promise cl .43
Promise sicl, c .49
Promise sicl .37
Providence .37
Pullman sicl, cl .43

Quinlan l .24

Raber sil .37
Rabun .32
Paens vfsl .32
Ramsey .28
Ranger .37
Rapidan .37
Rarden .43
Raritan .43
Rayne sil .28
Readington .43
Red Bay .28
Regent cl .43
Regent sicl .37
Reinach fsl .24
Reliance sicl, sil .32
Renfrow sil, cl .49
Renox .32
Renshaw l .24
Renshaw sl .20
Rentide sicl .43
Rhoades l .49
Richfield sil, cl, l .37
Richfield fsl .32
Riverton l, sic .49
Robertsdale .43
Rockcastle .43
Rohrersville .43
Rolla c .43
Rosebud sil .24
Rosebud sl .20
Roseglen sil .32
Rossnoyne .27
Roxbury sicl .37
Rumford lfs .20
Runge fsl .28
Runge scl .32
Russellville .37
Ruston fsl .28
Ruston lfs, sil .24
Ruxton, stony .20

Saffell, gr sl .20
St. Lucie .32
St. Lucie fs .17
St. Paul sil, l .32
Salemsburg sil .32
Salvisa .43
San Antonio fsl .43
Sanderson gr. l .24
Sango .43
San Saba c .32
Sassafras, th. sur. .20
Sassafras .28
Savannah fsl .37
Savage sicl .37
Savage sil .32
Sawyer fsl .43
Sawyer lfs .32
Sciotoville .43
Scranton .20
Searing l, sil .28
Sees, sicl .37
Sequatchie .28
Sequoia .43
Sharpsburg sil .37
Shelby cl, sil .37
Shelbyville .37
Shellabarger l, fsl .24
Shellabarger lfs .20
Shelocta .32
Shouns .28
Shrouts .43
Shubuta .43
Silerton .42
Simona fsl .24
Sinai sic .43
Sinai sicl .37
Singsaas l .32
Sioux l, sl .24
Sioux, gr. l .20
Smolin sicl .43
Sogn sicl .32
Spearfish l, sil .28
Spotswood l .24
Springer sfl .20
Springer lfs .17
Springfield .43

Table 1a Continued

Stamford c .43
Starr .42
State .28
Steekee .37
Steinauer .28
Stegall l .37
Stephenville l, fsl, lfs .24
Stephen sic .37
Stephensville fsl .24
Stidham fsl .28
Stidham lfs .24
Stough .43
Stuttgart .43
Sulphura .32
Summerfield .43
Summit sicl .43
Sumter .49
Sunsweet .43
Surry .37
Susquehanna fsl .49
Svea l, sil .32
Swaim .43
Switzer sicl .49
Sylvatus .37

Tabler sil, sicl .49
Tabor fsl .49
Taft .43
Talbott .43
Talihina cl .24
Talladega .37
Talladega, deep .32
Taloka sil .37

Tate fsl .28
Tatum .43
Teas sil .32
Teas, sh. sil .24
Teller fsl, sl .24
Teller l, sil .28
Tellico .32
Tescott sil .43
Thomasville fsl .32
Thurman sl .17
Thurmont, gr. .24
Tickfaw .43
Tifton .28
Tilden fsl .37
Tillman cl .43
Tilsit .43
Timmer fsl .32
Tippah sil .43
Tipton l, cl .32
Tipton sil, fsl .24
Tirzah .32
Tishomingo .43
Tivoli, fs .17
Tobosa c .37
Tolley l .28
Townly sicl .37
Trappist .37
Travessilli, stony l .24
Travis fsl .32
Trego .43
Trent sicl .32
Trinity c .32
Tripp sil .32

Truce fsl .43
Tully sicl .37
Tumbez .32
Tupelo .43
Tusquitee .24
Tyler sil .43

Ulen fsl, sl .20
Ulen ls .17
Ulysses sil .28
Ulysses cl .32
Uniontown .37
Unison .28
Upshur .43
Upton gr. l .24
Uvalde sicl .28

Vaiden .43
Vale l, sil, cl, sicl .37
Valentine ls, fs .17
Valentine s .15
Valera c .37
Vance .43
Vanoss fsl, sil .28
Vaucluse .37
Vebar lfs .17
Vebar sl, l, fsl .20
Venus cl .37
Verdel c .49
Verdun .43
Vernon c .43
Victoria c .32

Vienna sl .28
Vienna l .32
Vona fsl .20
Vona lfs .17

Wade l .49
Wadesboro .37
Wahee fsl .28
Wallston l .32
Wando .17
Watauga .32
Watt .43
Waubay sicl .32
Waugh .40
Waurika sil .49
Waynesboro .32
Waynesboro, gr. .24
Webb fsl .37
Weinbach .43
Wellston .32
Wessington fsl .20
Wessington l .24
Westfall sil .37
Westmoreland sil .37
Weymouth cl .37
Wharton .43
Wheeling .32
Wheeling, gr. .24
Whiteford .32
White Store .49
Whitwell .32
Wichita cl .37
Wichita fsl .28

Wickham .37
Wickham, friable .37
Wilcox .49
Wilkes .43
Willacy fsl, l .24
Williams cl .37
Williams l, sil .32
Wilson cl .43
Windthorst fsl .37
Wolftever .43
Woodson sil, sicl .49
Woodstown .28
Woodward l .28
Woolper .32
Worsham .43
Wymore sicl .43

Yadkin .37
Yahola fsl .28
Yale .37
York .43

Zaar c .49
Zahl l .32
Zaleski .37
Zaneis l, fsl .24
Zanesville fsl .24
Zanesville .32
Zapata gr. l. .24
Zell sil .32
Zita l .32
Zita fsl .28
Zoar .43

Table 1b

DESCRIPTIONS OF THE SOIL UNITS

1 - Deep, fine-textured, very slowly permeable soils.
2 - Deep, fine-textured, slowly permeable soils.
2X - Deep, fine-textured, moderately permeable soils.
3 - Deep, fine-textured, very slowly permeable bottomland soils.
4 - Deep, fine-textured, slowly permeable bottomland soils.
4X - Deep, fine-textured, moderately permeable bottomland soils.
5 - Deep, medium-textured, very slowly permeable soils.
6 - Deep, medium-textured, slowly permeable soils.
7 - Deep, medium-textured, moderately permeable soils.
7X - Deep, medium-textured, rapidly permeable soils.
8 - Deep, medium-textured, slowly permeable bottomland soils.
9 - Deep, medium-textured, moderately permeable bottomland soils.
10 - Deep, coarse-textured, very slowly permeable soils.
11 - Deep, coarse-textured, slowly permeable soils.
12 - Deep, coarse-textured, moderately permeable soils.
12X - Deep, coarse-textured, moderately rapidly permeable soils.
13 - Deep, coarse-textured, rapidly permeable soils.
14 - Deep, coarse-textured, slowly permeable bottomland soils.
15 - Deep, coarse-textured, moderately permeable bottomland soils.
15X - Deep, coarse-textured, rapidly permeable bottomland soils.
16 - Shallow, fine-textured, very slowly permeable soils.
17 - Shallow, fine-textured, slowly permeable soils.
18 - Shallow, fine-textured, moderately permeable soils.
19 - Shallow, medium-textured, very slowly or slowly permeable soils.
20 - Shallow, medium-textured, moderately permeable or rapidly permeable soils.
21 - Shallow, coarse-textured, slowly permeable soils.
22 - Shallow, coarse-textured, moderately permeable soils.
23 - Shallow, coarse-textured, rapidly permeable soils.
24 - Very shallow, fine-textured soils.
25 - Very shallow, medium-textured soils.
26 - Very shallow, coarse-textured soils.
27 - Rough broken or rough stony land, non-calcareous materials.
28 - Rough broken or rough stony land, calcareous materials.
29 - Organic soils (peat and muck).
30 - Mixed, very shallow, shallow and deep sandy lands.
31 - Mixed, very shallow, shallow and deep heavy lands.
32 - Not used.
33 - Non-arable, alluvial soils, undifferentiated.

a. Moderately wet soils.
c. Stony soils.
d. Cherty or gravelly soils.
f. High lime soils.

4-19870

Table 2

COVER ADJUSTMENT FACTORS – CROPLAND

Based on Following Relative Erosion Rates: Row Crop 1.00
Small Grain .30
Hay-Pasture .10

Percent Small Grains - Fall Planted (Read down)

| Row Crop Percent | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .10 | .11 | .12 | .13 | .14 | .15 | .16 | .17 | .18 | .19 | .20 | .21 | .22 | .23 | .24 | .25 | .26 | .27 | .28 | .29 | .30 |
| 5 | .15 | .16 | .17 | .18 | .19 | .20 | .21 | .22 | .23 | .24 | .25 | .26 | .27 | .28 | .29 | .30 | .31 | .32 | .33 | .34 | |
| 10 | .19 | .20 | .21 | .22 | .23 | .24 | .25 | .26 | .27 | .28 | .29 | .30 | .31 | .32 | .33 | .34 | .35 | .36 | .37 | | |
| 15 | .24 | .25 | .26 | .27 | .28 | .29 | .30 | .31 | .32 | .33 | .34 | .35 | .36 | .37 | .38 | .39 | .40 | .41 | | 1.00 | 100 |
| 20 | .28 | .29 | .30 | .31 | .32 | .33 | .34 | .35 | .36 | .37 | .38 | .39 | .40 | .41 | .42 | .43 | .44 | | .98 | .96 | 95 |
| 25 | .33 | .34 | .35 | .36 | .37 | .38 | .39 | .40 | .41 | .42 | .43 | .44 | .45 | .46 | .47 | .48 | | .94 | .93 | .91 | 90 |
| 30 | .37 | .38 | .39 | .40 | .41 | .42 | .43 | .44 | .45 | .46 | .47 | .48 | .49 | .50 | .51 | | .92 | .90 | .89 | .87 | 85 |
| 35 | .42 | .43 | .44 | .45 | .46 | .47 | .48 | .49 | .50 | .51 | .52 | .53 | .54 | .55 | | .88 | .87 | .85 | .84 | .82 | 80 |
| 40 | .46 | .47 | .48 | .49 | .50 | .51 | .52 | .53 | .54 | .55 | .56 | .57 | .58 | | .86 | .84 | .83 | .81 | .80 | .78 | 75 |
| 45 | .51 | .52 | .53 | .54 | .55 | .56 | .57 | .58 | .59 | .60 | .61 | .62 | | .82 | .81 | .79 | .78 | .76 | .75 | .73 | 70 |
| 50 | .55 | .56 | .57 | .58 | .59 | .60 | .61 | .62 | .63 | .64 | .65 | | .79 | .78 | .77 | .75 | .74 | .72 | .71 | .69 | 65 |
| 55 | .60 | .61 | .62 | .63 | .64 | .65 | .66 | .67 | .68 | .69 | | .76 | .75 | .73 | .72 | .70 | .69 | .67 | .66 | .64 | 60 |
| 60 | .64 | .65 | .66 | .67 | .68 | .69 | .70 | .71 | .72 | | .74 | .72 | .71 | .69 | .68 | .66 | .65 | .63 | .62 | .60 | 55 |
| 65 | .69 | .70 | .71 | .72 | .73 | .74 | .75 | .76 | | .70 | .69 | .67 | .66 | .64 | .63 | .61 | .60 | .58 | .57 | .55 | 50 |
| 70 | .73 | .74 | .75 | .76 | .77 | .78 | .79 | | .68 | .66 | .65 | .63 | .61 | .60 | .59 | .57 | .56 | .54 | .53 | .51 | 45 |
| 75 | .78 | .79 | .80 | .81 | .82 | .83 | | .64 | .63 | .61 | .60 | .58 | .57 | .55 | .54 | .52 | .51 | .49 | .48 | .46 | 40 |
| 80 | .82 | .83 | .84 | .85 | .86 | | .61 | .60 | .59 | .57 | .56 | .54 | .53 | .51 | .50 | .48 | .47 | .45 | .44 | .42 | 35 |
| 85 | .87 | .88 | .89 | .90 | | .58 | .57 | .55 | .54 | .52 | .51 | .49 | .48 | .46 | .45 | .43 | .42 | .40 | .39 | .37 | 30 |
| 90 | .91 | .92 | .93 | | .56 | .54 | .53 | .51 | .50 | .48 | .47 | .45 | .44 | .42 | .41 | .39 | .38 | .36 | .35 | .33 | 25 |
| 95 | .96 | .97 | | .52 | .51 | .49 | .48 | .46 | .45 | .43 | .42 | .40 | .39 | .37 | .36 | .34 | .33 | .31 | .30 | .28 | 20 |
| 100 | 1.00 | | .50 | .48 | .47 | .45 | .44 | .42 | .41 | .39 | .38 | .36 | .35 | .33 | .32 | .30 | .29 | .27 | .26 | .24 | 15 |
| | | .46 | .45 | .43 | .42 | .40 | .39 | .37 | .36 | .34 | .33 | .31 | .30 | .28 | .27 | .25 | .24 | .22 | .21 | .19 | 10 |
| | .44 | .42 | .41 | .39 | .38 | .36 | .35 | .33 | .32 | .30 | .29 | .27 | .26 | .24 | .23 | .21 | .20 | .18 | .17 | .15 | 5 |
| 40 | .39 | .37 | .36 | .34 | .33 | .31 | .30 | .28 | .27 | .25 | .24 | .22 | .21 | .19 | .18 | .16 | .15 | .13 | .12 | .10 | 0 |
| 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 | 50 | 45 | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | % Row |

Percent Small Grains (Spring Planted) Read Up

Based on Following Relative Erosion Rates - Row Crop = 1.00; Small Grains = .40; Hay & Pasture = .10

Table 3

RELATIVE RATES OF EROSION UNDER VARIOUS TYPES OF COVER AND COVER CONDITIONS

| Type and Cover Condition | Percent of Row Crop Erosion Rate |
|---|---|
| Row Crop - Poor or No Rotation | 0.80-1.00 1/ |
| Small Grains (Fall Planted) | 0.30-0.40 1/ |
| Small Grains (Spring Planted) | 0.40-0.50 1/ |
| Grasses and Legumes in Rotation | 0.10-0.20 1/ |
| Pasture Excellent Cover | .01 2/ |
| Pasture Good Cover | .03 2/ |
| Pasture Fair Cover | .07 2/ |
| Pasture Poor Cover | .15 2/ |
| Pasture Very Poor Cover or Idle | .30 2/ |
| Woods Good Cover | .01 1/ |
| Woods Fair Cover | .03 1/ |
| Woods Poor Cover | .07 1/ |

Reference:

1/ Time Table Study, June 1949

2/ Estimated: Pasture and woods factors can be raised or lowered, based on the judgment of the geologist. For example: pasture fair cover could range from .04-.14.

COVER DENSITY GUIDE

| Cover Condition | Ground Cover Including Litter (%) |
|---|---|
| Excellent | 90 - 100 |
| Good | 70 - 89 |
| Fair | 50 - 69 |
| Poor | 30 - 49 |
| Very Poor | 15 - 29 |

Table 4

## ADJUSTMENT FACTORS FOR SLOPE PERCENT* AND SLOPE LENGTH

| Percent | SLOPE LENGTH (Feet) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Slope | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 50 | 60 | 72.6 | 80 | 90 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 350 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
| .5 | .0084 | .0096 | .0107 | .0115 | .0124 | .0131 | .0150 | .0160 | .0170 | .0190 | .0190 | .0200 | .0210 | .022 | .024 | .025 | .026 | .027 | .028 | .029 | .029 | .030 | .031 | .032 | .034 | .037 | .039 | .042 | .044 | .046 | .048 |
| 1.0 | .0216 | .0246 | .0273 | .0295 | .0317 | .0334 | .0360 | .0390 | .0420 | .0450 | .0460 | .0480 | .0500 | .053 | .056 | .059 | .061 | .063 | .066 | .068 | .070 | .072 | .073 | .077 | .081 | .089 | .094 | .099 | .104 | .109 | .113 |
| 2.0 | .0559 | .0638 | .0707 | .0764 | .0821 | .0866 | .0920 | .1000 | .1070 | .1150 | .1180 | .1240 | .1280 | .137 | .145 | .150 | .157 | .162 | .170 | .173 | .178 | .184 | .187 | .197 | .207 | .228 | .239 | .253 | .266 | .278 | .289 |
| 3.0 | .0956 | .1092 | .1209 | .1306 | .1404 | .1482 | .1530 | .1670 | .1780 | .1920 | .1970 | .2070 | .2150 | .228 | .242 | .251 | .263 | .270 | .284 | .290 | .297 | .307 | .313 | .330 | .345 | .380 | .399 | .422 | .443 | .465 | .482 |
| 4.0 | .1416 | .1618 | .1792 | .1936 | .2081 | .2196 | .2280 | .2480 | .2650 | .2850 | .2930 | .3080 | .3190 | .339 | .359 | .373 | .390 | .402 | .422 | .430 | .442 | .456 | .464 | .490 | .513 | .564 | .593 | .627 | .658 | .690 | .715 |
| 5.0 | .1906 | .2178 | .2412 | .2606 | .2801 | .2956 | .3090 | .3360 | .3590 | .3780 | .3860 | .4170 | .4320 | .459 | .486 | .506 | .529 | .544 | .571 | .582 | .598 | .618 | .629 | .664 | .695 | .764 | .803 | .849 | .892 | .934 | .969 |
| 6.0 | .2426 | .2772 | .3069 | .3316 | .3564 | .3762 | .3960 | .4320 | .4620 | .4970 | .5120 | .5370 | .5570 | .591 | .626 | .651 | .681 | .701 | .735 | .750 | .770 | .795 | .810 | .855 | .895 | .984 | 1,034 | 1.093 | 1.148 | 1.203 | 1.247 |
| 7.0 | .2989 | .3416 | .3782 | .4087 | .4392 | .4636 | .4890 | .5310 | .5680 | .6110 | .6290 | .6600 | .6840 | .727 | .770 | .800 | .837 | .861 | .904 | .923 | .947 | .977 | .996 | 1.051 | 1.100 | 1.210 | 1.271 | 1.344 | 1.411 | 1.479 | 1.534 |
| 8.0 | .3601 | .4116 | .4557 | .4924 | .5292 | .5586 | .5850 | .6360 | .6800 | .7310 | .7530 | .7890 | .8190 | .870 | .921 | .957 | 1.001 | 1.031 | 1.082 | 1.104 | 1.133 | 1.169 | 1.191 | 1.257 | 1.316 | 1.447 | 1.520 | 1.608 | 1.689 | 1.769 | 1.835 |
| 9.0 | .4302 | .4917 | .5444 | .5883 | .6322 | .6673 | .6830 | .7430 | .7940 | .8540 | .8790 | .9220 | .9560 | 1.016 | 1.102 | 1.136 | 1.170 | 1.204 | 1.264 | 1.289 | 1.324 | 1.366 | 1.392 | 1.469 | 1.537 | 1.691 | 1.776 | 1.879 | 1.973 | 2.067 | 2.143 |
| 10.0 | .4900 | .5600 | .6200 | .6700 | .7200 | .7600 | .8000 | .8700 | .9300 | 1.0000 | 1.0300 | 1.1800 | 1.1200 | 1.190 | 1.260 | 1.310 | 1.370 | 1.410 | 1.480 | 1.510 | 1.550 | 1.600 | 1.630 | 1.720 | 1.800 | 1.980 | 2.080 | 2.200 | 2.310 | 2.420 | 2.510 |
| 11.0 | .5586 | .6384 | .7068 | .7638 | .8208 | .8664 | .8980 | .9770 | 1.0440 | 1.1230 | 1.1570 | 1.2130 | 1.2580 | 1.336 | 1.415 | 1.471 | 1.538 | 1.583 | 1.662 | 1.696 | 1.741 | 1.797 | 1.830 | 1.931 | 2.021 | 2.223 | 2.336 | 2.471 | 2.594 | 2.718 | 2.819 |
| 12.0 | .6272 | .7168 | .7936 | .8576 | .9216 | .9728 | 1.0090 | 1.0980 | 1.1740 | 1.2620 | 1.3000 | 1.3630 | 1.4130 | 1.502 | 1.590 | 1.653 | 1.729 | 1.779 | 1.868 | 1.906 | 1.956 | 2.019 | 2.057 | 2.171 | 2.272 | 2.499 | 2.625 | 2.776 | 2.915 | 3.054 | 3.168 |
| 13.0 | .7056 | .8064 | .8928 | .9648 | 1.0368 | 1.0944 | 1.1320 | 1.2310 | 1.3160 | 1.4150 | 1.4570 | 1.5280 | 1.5850 | 1.684 | 1.783 | 1.854 | 1.938 | 1.995 | | | | | | | | | | | | | |
| 14.0 | .7742 | .8848 | .9796 | 1.0586 | 1.1376 | 1.2008 | 1.2550 | 1.3650 | 1.4590 | 1.5690 | 1.6160 | 1.6940 | 1.7570 | 1.867 | 1.977 | 2.055 | 2.149 | 2.212 | | | | | | | | | | | | | |
| 15.0 | .8428 | .9632 | 1.0664 | 1.1524 | 1.2384 | 1.3072 | 1.3780 | 1.4990 | 1.6020 | 1.7230 | 1.7750 | 1.8610 | 1.9300 | 2.050 | 2.171 | 2.257 | 2.360 | 2.429 | | | | | | | | | | | | | |
| 20.0 | 1.2495 | 1.4280 | 1.6210 | 1.7085 | 1.8770 | 1.9380 | 2.0145 | 2.1930 | 2.3460 | 2.4990 | 2.6265 | 2.8560 | 3.0600 | | | | | | | | | | | | | | | | | | |
| 25.0 | 1.6905 | 1.9320 | 2.1900 | 2.3115 | 2.5030 | 2.6220 | 2.7255 | 2.9670 | 3.1740 | 3.3810 | 3.5535 | 3.8640 | 4,1400 | | | | | | | | | | | | | | | | | | |
| 30.0 | 2.1805 | 2,4920 | 2.8160 | 2.9815 | 3.2610 | 3.3820 | 3.5155 | 3.8270 | 4.0940 | 4.3610 | 4.5835 | 4.9840 | 5.3400 | | | | | | | | | | | | | | | | | | |
| 35.0 | 2.6950 | 3.0800 | 3.4700 | 3.6850 | 4.0190 | 4.1800 | 4.3450 | 4.7300 | 5,0600 | 5.3900 | 5.6650 | 6.1600 | 6.6000 | | | | | | | | | | | | | | | | | | |
| 40.0 | 3.1850 | 3.6400 | 4.1810 | 4.3550 | 4.8750 | 4.9400 | 5.1350 | 5.5900 | 5.9800 | 6.3700 | 6.6950 | 7.2800 | 7.8000 | | | | | | | | | | | | | | | | | | |
| 50.0 | 4.3120 | 4.9280 | 5.4560 | 5.8960 | 6.3360 | 6.6880 | 6.9520 | 7.5680 | 8.0960 | 8.6240 | 9.0640 | 9.8560 | 10.5600 | | | | | | | | | | | | | | | | | | |

* Based on 10% slope

4-19870

PROPOSED FORM

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Table 5 - WATERSHED SHEET EROSION DATA

Elm Creek Watershed

Site No. 10 Planning No. ______ County Hill Area: Acres 960 Sq. Mi. 1.5

Land Resource Area Blackland Prairies Computed by Sam Spade Date ______

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land Use | | | Cultivated | | | | | | Pasture Woods | | Land Cap. Class | Slope | | | Vol.Wt. Lbs./ Cu. Ft. | Area (Ac) | Ero.Rate Tons/ Acre/Yr. | Adjustment Factors | | | | | Soil Loss (Tons/Yr.) | |
| | | Soil Unit | %Row Cr. | | % Other | | Terraced | | | | | % | Length | | | | | Slope | | Cover | | Rain Fall | | |
| Pres | Fut | | Pres | Fut | Pres | Fut | Pres | Fut | Pres | Fut | | | Pres | Fut | | | | Pres | Fut | Pres | Fut | | Pres | Fut |
| L | L | 1 | 100 | 75 | | 25 | None | T | | | II | 3 | 300 | 80 | 82 | 100 | 97 | .313 | .197 | 1.00 | .83 | 1.30 | 3947 | 2062 |
| L | L | 1 | 100 | 75 | | 25 | T | T | | | II | 3 | 80 | 80 | 82 | 300 | 97 | .197 | .197 | 1.00 | .83 | 1.30 | 7453 | 6186 |
| L | L | 1 | | | 100 | 100 | None | None | | | II | 3 | 300 | 300 | 82 | 400 | 97 | .313 | .313 | .30 | .30 | 1.30 | 4736 | 4736 |
| P | P | 1 | | | | | | | F * | G | III | 4 | 100 | 100 | 82 | 160 | 97 | .319 | .319 | .10 | .05 | 1.30 | 644 | 322 |
| | | | | | | | | | | | | | | | | | | | | TOTALS | | | 16780 | 13306 |

* - PASTURE COVER CONDITIONS
P = Poor
F = Fair
G = Good

Solution for soil loss (present) = Column 17 x 18 x 19 x 21 x 23 = Column 24
Solution for soil loss (future) = Column 17 x 18 x 20 x 22 x 23 = Column 25

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Table 6 - ANNUAL GULLY OR STREAMBANK EROSION

Elm Creek Watershed

Site No. 10 Planning No. ______ County Hill Acres 960 Sq. Mi. 1.50

Land Resource Area Blackland Prairies Computed by Sam Spade Date ______

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Erosion | | | Length (Ft.) | Percent Affected | Av. Ht. of Bank (Ft.) | Annual Lateral Erosion (Ft.) | Weight Pounds Per Cu.Ft. | Annual Erosion | | Annual Erosion | | REMARKS |
| Gully | Stream-bank | Road-side | | | | | | Present (Pounds) | Future (Pounds) | (Tons) Present | (Tons) Future | |
| X | | | 1,800 | 50 | 4 | 0.20 | 83 | 59,760 | 44,000 | 30 | 22 | |
| | | X | 3,000 | 50 | 3 | 0.10 | 83 | 37,350 | 28,000 | 18 | 14 | |
| | X | | 2,250 | 80 | 5 | 0.10 | 83 | 74,700 | 56,000 | 37 | 28 | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | TOTALS | 85 | 64 | |

Solution - Column 4 x 5 x 6 x 7 x 8 = Column 9
Column 9 ÷ 2000 = Column 11
Column 10 ÷ 2000 = Column 12

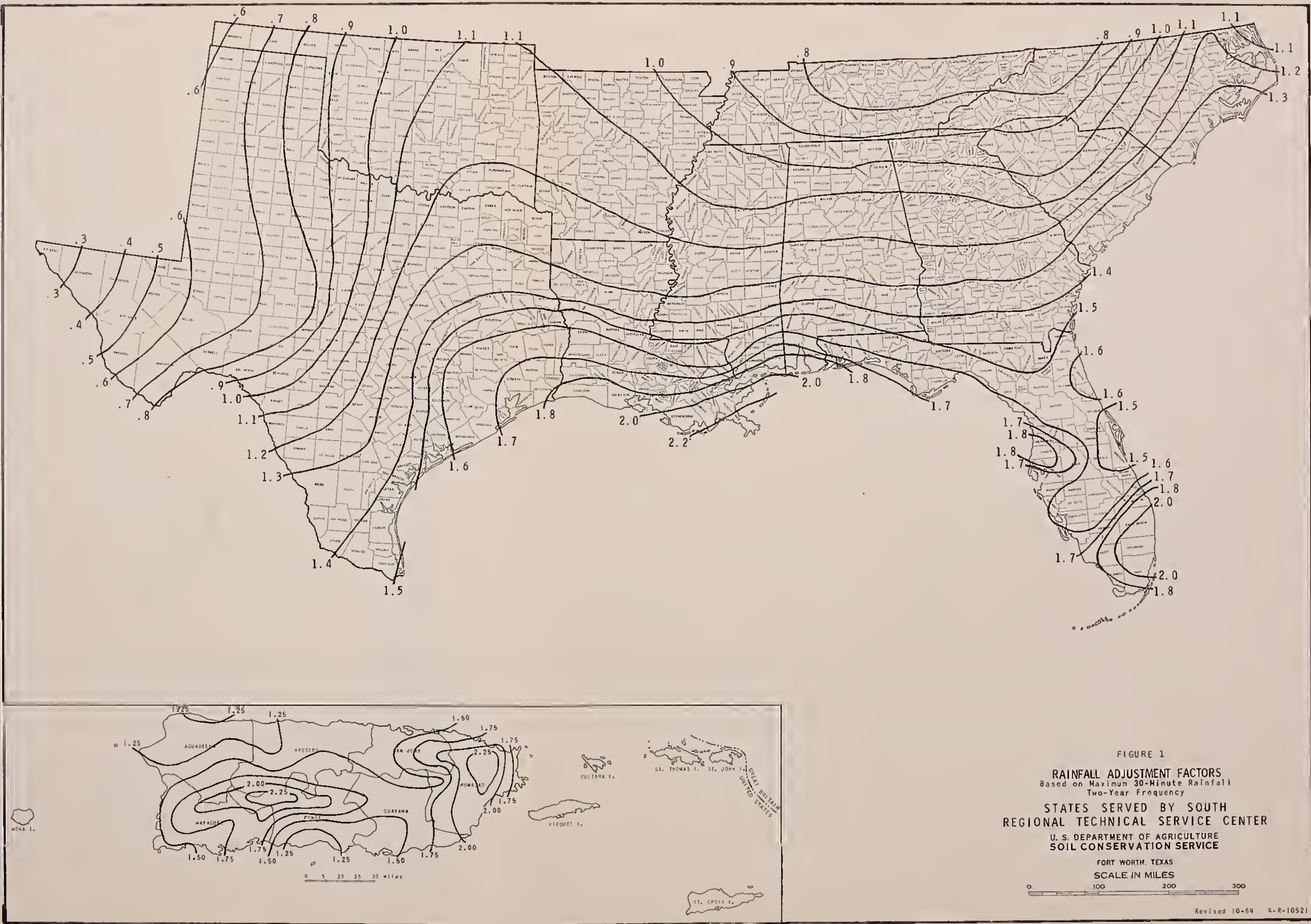



FIGURE 1

RAINFALL ADJUSTMENT FACTORS
Based on Maximum 30-Minute Rainfall
Two-Year Frequency

STATES SERVED BY SOUTH
REGIONAL TECHNICAL SERVICE CENTER

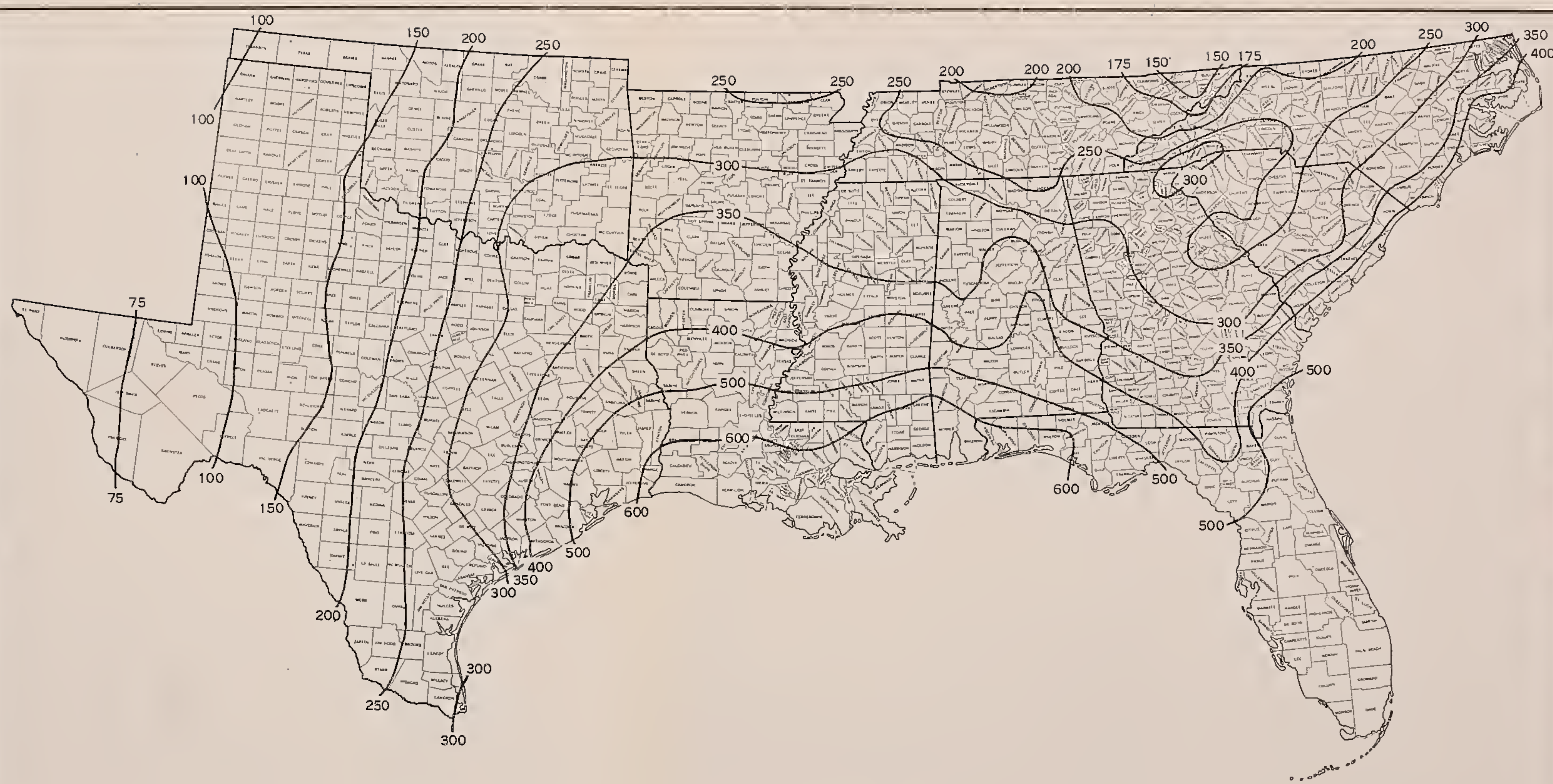
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FORT WORTH, TEXAS

Base from U. S. Department of Commerce, Bureau of the Census-1960

Revised 10-64 Base 4-R-10919

4-19870



1/ Rainfall-Erosion Losses From Cropland East of the Rocky Mountains. Agri. Handbook No. 282 USDA-ARS, May 1965.


Figure 1a

ISO-ERODENT MAP 1/

STATES SERVED BY SOUTH
REGIONAL TECHNICAL SERVICE CENTER

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FORT WORTH, TEXAS

SCALE IN MILES

0 100 200 300

10-67 4-R-24942

Base from U. S. Department of Commerce, Bureau of the Census-1960

Revised 10-64 Base 4-R-10919

4-19870

Table 7

CONVERSION TABLE (POUNDS PER CUBIC FOOT TO TONS PER ACRE-FOOT)

| Pounds per Cubic Foot | Tons per Acre-Foot | Acre-Feet per Ton | Acre-Inches per Ton |
|---|---|---|---|
| 30 | 653.40 | 0.001531 | 0.018366 |
| 31 | 675.18 | 0.001481 | 0.017772 |
| 32 | 696.96 | 0.001435 | 0.017220 |
| 33 | 718.74 | 0.001392 | 0.016704 |
| 34 | 740.52 | 0.001350 | 0.016200 |
| 35 | 762.30 | 0.001312 | 0.015744 |
| 36 | 784.08 | 0.001275 | 0.015300 |
| 37 | 805.86 | 0.001241 | 0.014892 |
| 38 | 827.64 | 0.001208 | 0.014496 |
| 39 | 849.42 | 0.001177 | 0.014124 |
| 40 | 871.20 | 0.001148 | 0.013776 |
| 41 | 892.98 | 0.001120 | 0.013440 |
| 42 | 914.76 | 0.001093 | 0.013116 |
| 43 | 936.54 | 0.001068 | 0.012816 |
| 44 | 958.32 | 0.001043 | 0.012516 |
| 45 | 980.10 | 0.001020 | 0.012240 |
| 46 | 1001.88 | 0.000998 | 0.011976 |
| 47 | 1023.66 | 0.000977 | 0.011724 |
| 48 | 1045.44 | 0.000956 | 0.011472 |
| 49 | 1067.22 | 0.000937 | 0.011244 |
| 50 | 1089.00 | 0.000918 | 0.011016 |
| 51 | 1110.78 | 0.000900 | 0.010800 |
| 52 | 1132.56 | 0.000883 | 0.010596 |
| 53 | 1154.34 | 0.000866 | 0.010392 |
| 54 | 1176.12 | 0.000850 | 0.010200 |
| 55 | 1197.90 | 0.000835 | 0.010020 |
| 56 | 1219.46 | 0.000820 | 0.009840 |
| 57 | 1241.46 | 0.000806 | 0.009672 |
| 58 | 1263.24 | 0.000791 | 0.009492 |
| 59 | 1285.02 | 0.000778 | 0.009336 |
| 60 | 1306.80 | 0.000765 | 0.009180 |
| 61 | 1328.58 | 0.000753 | 0.009036 |
| 62.42 | 1359.51 | 0.000736 | 0.008832 |
| 62.5 | 1361.25 | 0.000735 | 0.008820 |
| 63 | 1372.14 | 0.000729 | 0.008748 |
| 64 | 1393.92 | 0.000717 | 0.008604 |
| 65 | 1415.70 | 0.000706 | 0.008472 |
| 66 | 1437.48 | 0.000695 | 0.008340 |
| 67 | 1459.26 | 0.000685 | 0.008220 |
| 68 | 1481.04 | 0.000675 | 0.008100 |
| 69 | 1502.82 | 0.000665 | 0.007980 |
| 70 | 1524.60 | 0.000656 | 0.007872 |

Table 7 (Continued)

CONVERSION TABLE (POUNDS PER CUBIC FOOT TO TONS PER ACRE-FOOT)

| Pounds per Cubic Foot | Tons per Acre-Foot | Acre-Feet per Ton | Acre-Inches per Ton |
|---|---|---|---|
| 71 | 1546.38 | 0.000647 | 0.007764 |
| 72 | 1568.16 | 0.000637 | 0.007644 |
| 73 | 1589.94 | 0.000629 | 0.007548 |
| 74 | 1611.72 | 0.000620 | 0.007440 |
| 75 | 1633.50 | 0.000612 | 0.007344 |
| 76 | 1655.28 | 0.000604 | 0.007248 |
| 77 | 1677.06 | 0.000596 | 0.007152 |
| 78 | 1698.84 | 0.000588 | 0.007056 |
| 79 | 1720.62 | 0.000581 | 0.006972 |
| 80 | 1742.40 | 0.000574 | 0.006888 |
| 81 | 1764.18 | 0.000566 | 0.006792 |
| 82 | 1785.96 | 0.000560 | 0.006720 |
| 83 | 1807.74 | 0.000553 | 0.006636 |
| 84 | 1829.52 | 0.000546 | 0.006552 |
| 85 | 1851.30 | 0.000540 | 0.006480 |
| 86 | 1873.08 | 0.000534 | 0.006408 |
| 87 | 1894.86 | 0.000528 | 0.006336 |
| 88 | 1916.64 | 0.000522 | 0.006264 |
| 89 | 1938.42 | 0.000516 | 0.006192 |
| 90 | 1960.20 | 0.000510 | 0.006120 |
| 91 | 1981.98 | 0.000505 | 0.006060 |
| 92 | 2003.76 | 0.000499 | 0.005988 |
| 93 | 2025.54 | 0.000493 | 0.005916 |
| 94 | 2047.32 | 0.000488 | 0.005856 |
| 95 | 2069.10 | 0.000483 | 0.005796 |
| 96 | 2090.88 | 0.000478 | 0.005736 |
| 97 | 2112.66 | 0.000473 | 0.005676 |
| 98 | 2134.44 | 0.000469 | 0.005628 |
| 99 | 2156.22 | 0.000464 | 0.005568 |
| 100 | 2178.00 | 0.000459 | 0.005508 |
| 101 | 2199.78 | 0.000455 | 0.005460 |
| 102 | 2221.56 | 0.000450 | 0.005400 |
| 103 | 2243.34 | 0.000446 | 0.005352 |
| 104 | 2265.12 | 0.000441 | 0.005292 |
| 105 | 2286.90 | 0.000437 | 0.005244 |
| 106 | 2308.68 | 0.000433 | 0.005196 |
| 107 | 2330.46 | 0.000429 | 0.005148 |
| 108 | 2352.24 | 0.000425 | 0.005100 |
| 109 | 2374.02 | 0.000421 | 0.005052 |
| 110 | 2395.80 | 0.000417 | 0.005004 |

Table 7 (Continued)

CONVERSION TABLE (POUNDS PER CUBIC FOOT TO TONS PER ACRE-FOOT)

| Pounds per Cubic Foot | Tons per Acre-Foot | Acre-Feet per Ton | Acre-Inches per Ton |
|---|---|---|---|
| 111 | 2417.58 | 0.000414 | 0.004968 |
| 112 | 2439.36 | 0.000410 | 0.004920 |
| 113 | 2461.14 | 0.000406 | 0.004872 |
| 114 | 2482.92 | 0.000403 | 0.004836 |
| 115 | 2504.70 | 0.000399 | 0.004788 |
| 116 | 2526.48 | 0.000396 | 0.004752 |
| 117 | 2548.26 | 0.000392 | 0.004704 |
| 118 | 2570.04 | 0.000389 | 0.004668 |
| 119 | 2591.82 | 0.000386 | 0.004632 |
| 120 | 2613.60 | 0.000383 | 0.004596 |

Equations for computing tons per acre-foot; acre-feet per ton; and acre-inches per ton:

$$\text{Tons per acre-foot} = \frac{W \times 43{,}560}{2{,}000}$$

$$\text{Acre-feet per ton} = \frac{2{,}000}{W \times 43{,}560}$$

$$\text{Acre-inches per ton} = \frac{2{,}000 \times 12}{43{,}560}$$

Where:

W = Dry weight (lbs.) of one cubic foot of soil or sediment

43,560 = Cubic feet per acre-foot

2,000 = Pounds per ton

12 = Inches per foot

# CHAPTER VIII

## COMPUTATIONS OF SEDIMENT STORAGE REQUIREMENTS FOR SERVICE-DESIGNED STRUCTURES

The results of the investigations to determine gross erosion should be used to compute the sediment storage requirements for any Service-designed structure.

Sediment yield is dependent upon gross erosion from a watershed and the transport of the eroded material to a given point of measurement. In almost all watersheds the sediment delivered to any point during any period will be less than 100 percent of the gross erosion occurring above that point. Since only a part of the material set in motion by erosion processes is moved out of a watershed, the gross erosion figure must be adjusted downward to arrive at the sediment yield. This adjustment factor is the ratio of sediment yield to gross erosion and is termed the sediment delivery ratio. It is dependent upon several interrelated physical, hydrologic, hydraulic, and other watershed characteristics. If significant relationships between sediment delivery ratio and certain watershed characteristics can be established for a group of watersheds in a relatively homogeneous area, it is then possible to develop a procedure for making sound estimates of expected sediment yield from gross erosion data and the sediment delivery ratio characteristics of other watersheds within this area.

Reliable basic data on sediment yield is of major importance to the Soil Conservation Service in the development and application of the watershed protection and flood prevention phase of the overall program, which is designed to reduce upstream floodwater and sediment damages.

A study of the characteristics of the size of watershed variable, when used in a regression analysis with sediment delivery ratio, showed that the net influence of several watershed factors are represented in the derived equation for estimating sediment delivery ratio. For example, plottings on log-log paper revealed that watershed size is significantly related to the following measurable characteristics of the sample watersheds:

(1) Length of all channels: In this relatively homogeneous area total channel length was found to increase with an increase in size of watershed; (2) Channel density: In contrast to the large watersheds, small watersheds are found to have more linear feet of channels per unit of area; (3) Main stem channel length: The length of a main stem channel is directly related to the area of the watershed it serves; (4) Relief: Total relief increases with increasing watershed size; (5) Relief-length ratio: Large watersheds usually have lower relief-length ratio values than smaller watersheds in the same area; (6) Alluvial soils area: In contrast to small watersheds, larger watersheds usually have a greater proportion of their total area in alluvial soils, indicating an inverse relationship between watershed area and downstream delivery of erosional material.

The most significant variable has proved to be watershed area. The empirical relationship of sediment delivery ratio to watershed area is presented in the two delivery ratio curves in Figures 2 and 2A. It is recommended that Figure 2 be used where the majority of eroded material is fine to medium texture. Figure 2A can be used where a majority of

the eroded material is medium to coarse texture. A delivery ratio curve, based on the relationship of Relief-Length (R/L) Ratio, is included in Figure 3. It is recommended that this curve be used where a majority of the eroded material is medium to coarse texture.

The Form SCS-309, Reservoir Sedimentation Design Summary, is used for summarizing the sediment yield data into a realistic storage requirement. These delivery ratio curves are used to estimate sediment delivery from sheet and channel erosion.

Trap Efficiency

Studies made to the present time by the U. S. Geological Survey and the Agricultural Research Service indicate that the trap efficiency of Service-designed floodwater retarding structures averages 90-95 percent. It is recommended that work plan staff geologists use a trap efficiency of 90 or 95 percent when computing sediment storage requirements. For dry pools a lower trap efficiency, 80 to 85 percent, should be used.

Types of Sediment Source Studies

1. Detailed

For a detailed sediment source study the geologist should obtain a soils map of the drainage area above the structure site. The soils map should have 100 percent coverage of the area, or sufficient coverage to represent all soil and slope conditions. The soil-cover complex conditions, land use, land treatment, and slope lengths are mapped in the field. An overlay map of the drainage area, on transparent paper or acetate, is prepared showing:

a. Soil unit (series)

b. Slope (percent)

c. Slope length (feet)

d. Land use

e. Soil-cover complex conditions

f. Land treatment

g. Map scale

h. North arrow, title block, etc.

i. Stream pattern

j. Gully, roadside, and streambank erosion

The geologist measures each delineation with a planimeter or grid and tabulates all different combinations of slope, soil, and cover. These tabulations are summarized on a form similar to table 5 for computation of soil loss. Detailed computations usually are made for a representative number of drainage areas in each watershed. Normally up to a 25 percent sample of the sites will suffice.

VII

2. Semidetailed (Estimated)

An estimated or semidetailed sediment source study is one in which the geologist develops an erosion rate for each land use in a watershed from the detailed studies. An overlay on transparent paper or acetate is prepared for each drainage area with the following information delineated:

a. Stream pattern

b. Land use

c. Map scale, north arrow, title block, etc.

d. Gully, roadside, and streambank erosion

The geologist measures and tabulates each land use delineation. These data are summarized on Form SCS-309. Using the erosion rates developed for each land use, the sediment storage requirements are computed.

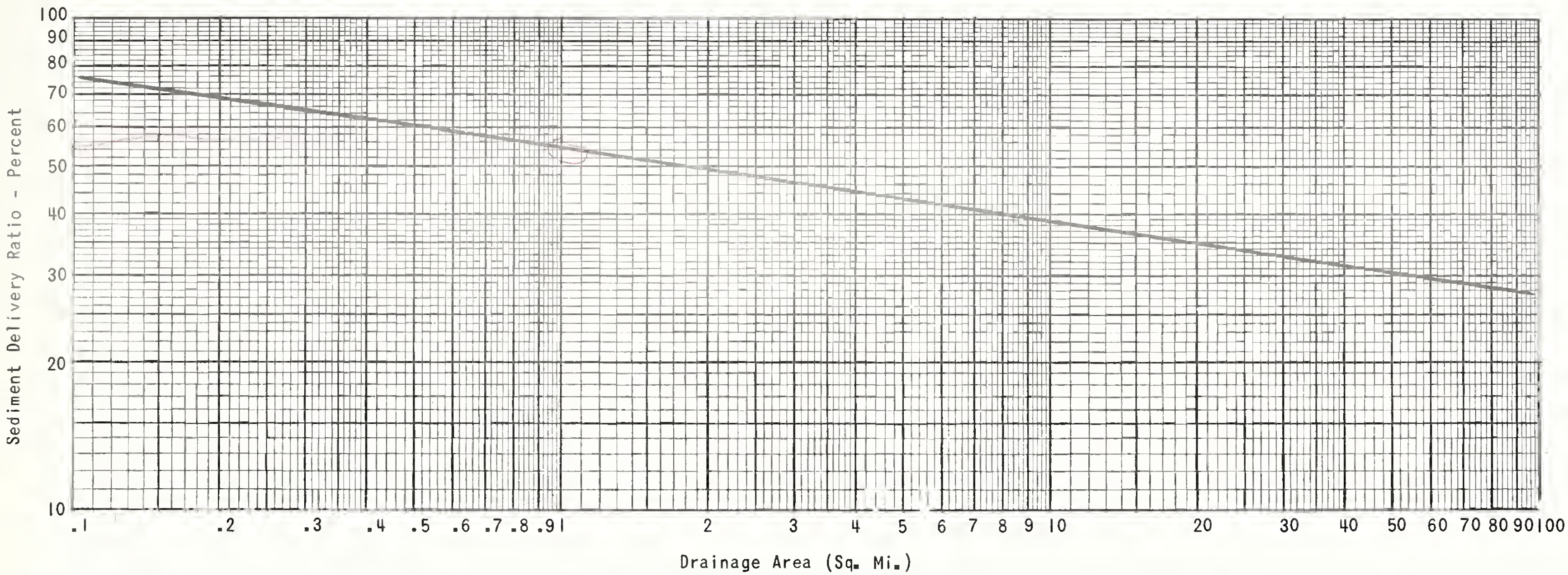



Figure 2

SEDIMENT DELIVERY RATIO CURVE
EROSION FROM ALL SOURCES

Data from Blackland Prairie Land Resource Area - Texas

Recommended Use: Where erosion is from fine and medium textured soils

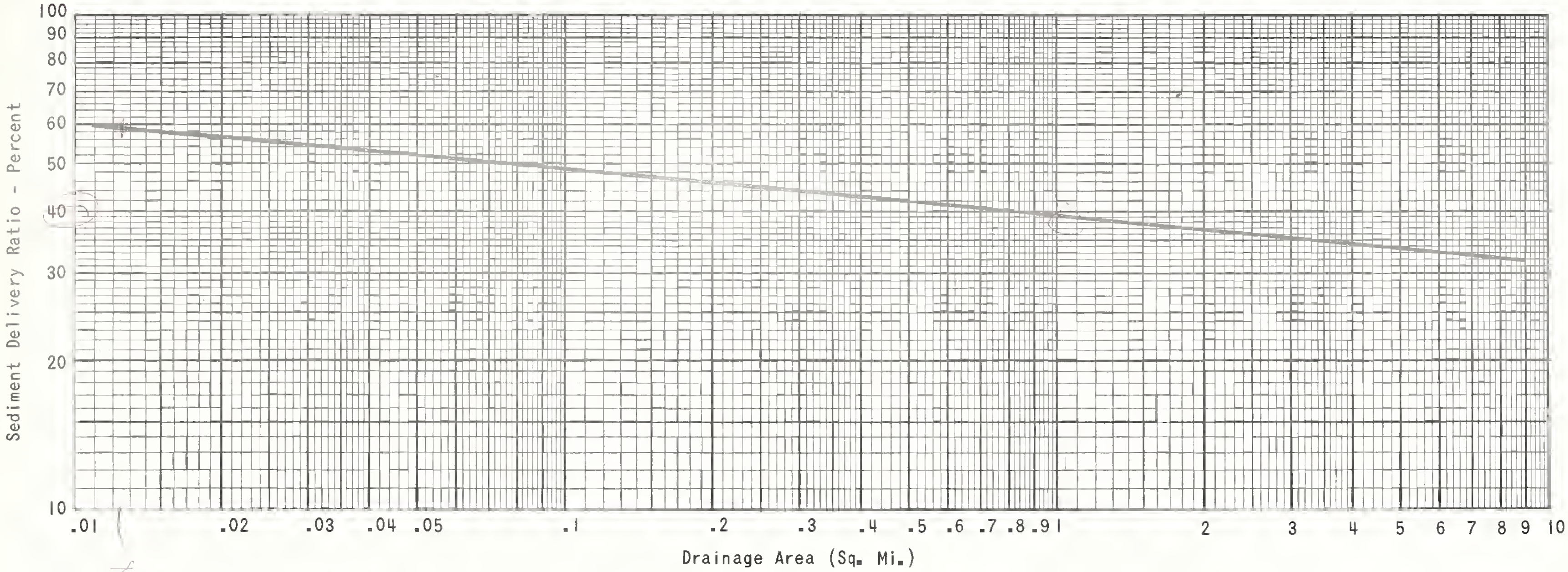



Figure 2-A

SEDIMENT DELIVERY RATIO CURVE
EROSION FROM ALL SOURCES

Data from Sand-Clay Hills Land Resource Area - Mississippi

Rrcommended Use: Where erosion is on medium and coarse textured soils

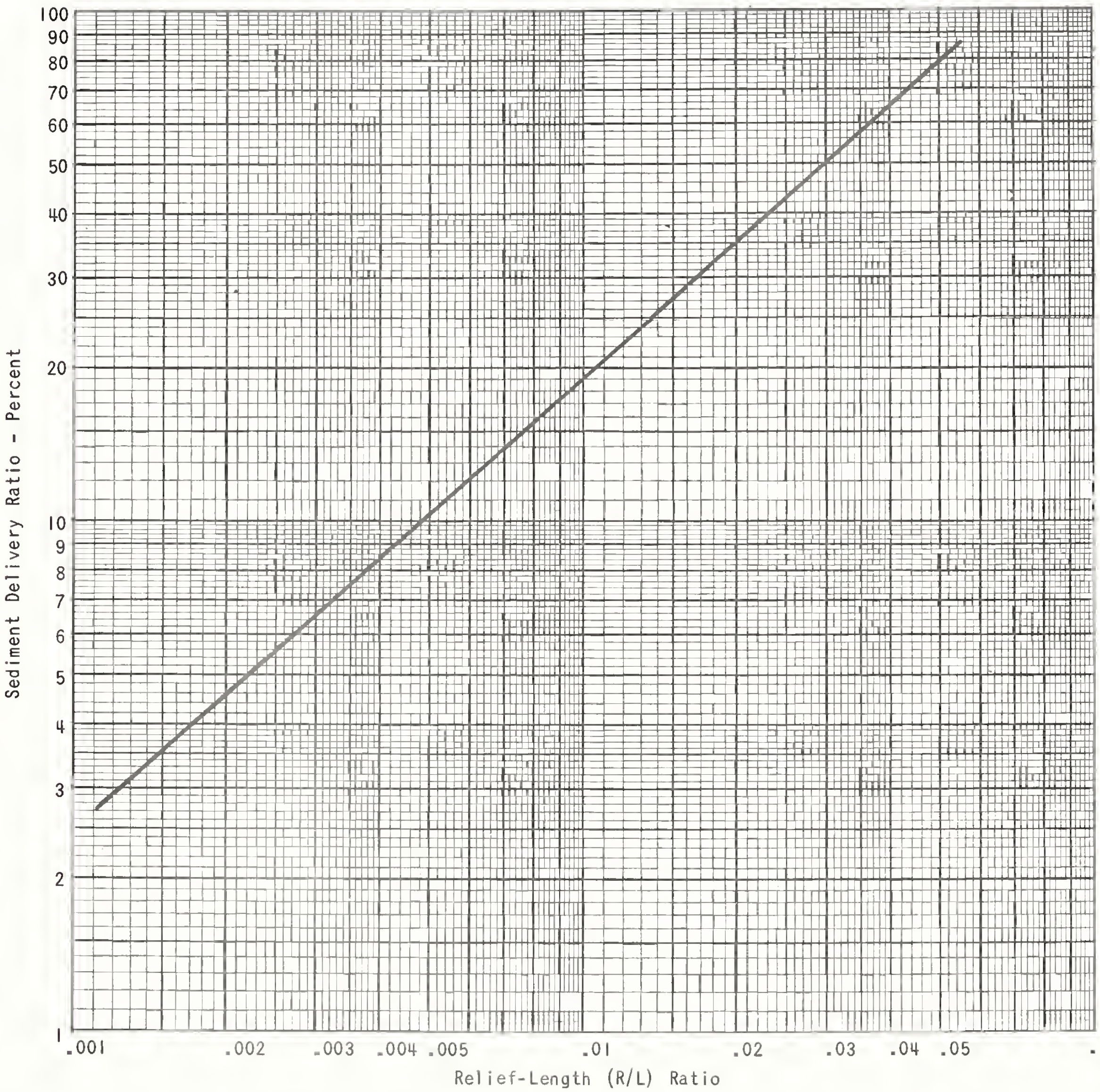



Figure 3

SEDIMENT DELIVERY RATIO CURVE
EROSION FROM ALL SOURCES

Data from Red Hills and Southern Piedmont Land Resource Areas

Recommended Use: Where erosion is on medium and coarse textured soils

# CHAPTER IX

## DISTRIBUTION AND ALLOCATION OF SEDIMENT IN WATERSHED RESERVOIRS

1. The percentage factors given below should be used only as a general guide because of the wide variations in erosion and mode of sediment deposition in the E&WP Unit area. Variations within watersheds above individual structures, including characteristics of the valley and stream channels should be considered, and percentage estimates adjusted accordingly for each site.

Suggested distribution and allocation of sediment storage in Service-designed structures is as follows:

a. Single-purpose floodwater retarding structures with 50- to 100-year life when the total sediment storage determines the elevation of the top of the riser.

| | Area 1 1/ | Area 2 1/ | Area 3 1/ | Area 4 1/ |
|---|---|---|---|---|
| Sediment Pool (submerged) | 90% | 80% | 70% | 60% |
| Detention Pool (aerated) | 10% | 20% | 30% | 40% |

1/ See attached Land Resource Area Map, Figure 4, of the States served by the Fort Worth Regional Technical Service Center.

Area 1 includes the following Land Resource Areas: 135 - Alabama and Mississippi Blackland Prairies; 76 - Bluestem Hills; 112 - Cherokee Prairies; 81 - Edwards Plateau; 85 - Grand Prairie; 150 - Gulf Coast Prairies; and 86 - Texas Blackland Prairie; 125 - Cumberland Plateau and Mountains.

Area 2 includes the following Land Resource Areas: 118 - Arkansas Valley and Ridges; 153 - Atlantic Coast Flatwoods; 80 - Central Rolling Red Prairies; 132 - Eastern Arkansas Prairies; 152 - Gulf Coast Flatwoods; 123 - Nashville Basin; 138 - Northern Central Florida Ridge; 119 - Ouachita Mountains; 116 - Ozark Highlands; 83 - Rio Grande Plain; 154 - South Florida Ridge; 128 - Southern Appalachian Ridges and Valleys; 133 - Southern Coastal Plain; 77 - Southern High Plains; 131 - Southern Mississippi Valley Alluvium; 134 - Southern Mississippi Valley Silty Uplands; 136 - Southern Piedmont; and 87 - Texas Claypan Area.

Area 3 includes the following Land Resource Areas: 78 - Central Rolling Red Plains; 84 - Cross Timbers; 122 - Highland Rim and Pennyroyal; 42 - Southern Desertic Basins, Plains and Mountains; 129 - Sand Mountain; and 137 - Carolina and Georgia Sandhills.

Area 4 includes the following Land Resource Areas: 130 - Blue Ridge; and 117 - Boston Mountains.

b. Multiple-purpose structure - 50- to 100-year life with floodwater detention storage.

| | Area 1 | Area 2 | Area 3 | Area 4 |
|---|---|---|---|---|
| Sediment and Multiple-Purpose Pools (submerged) 2/ | 90% | 80% | 70% | 60% |
| Detention Pool (aerated) | 10% | 20% | 30% | 40% |

c. Single-purpose storage reservoir - 50- to 100-year life and multiple-purpose storage reservoir without floodwater detention storage - 50- to 100-year life.

| | Area 1 | Area 2 | Area 3 | Area 4 |
|---|---|---|---|---|
| Sediment and Water Storage Pools (submerged) 2/ | 100% | 100% | 100% | 100% |

2/ Allocation of sediment within the various parts of the storage pool (for example, the recreation, irrigation, or municipal storages within the multiple-purpose pool) will be made in accordance with the probable actual sediment deposition estimated by the geologist, with due consideration of the composition and texture of the sediment, slope and relative volumes of the pools, size and slope of the drainage area, stream gradients, and other pertinent factors. (If the geologist considers it significant, above-crest deposits should be estimated.)

d. Single-purpose floodwater retarding structure with 50- to 100-year life with no provision for water storage in the sediment pool. (Dry Pool.)

| | Area 1 | Area 2 | Area 3 | Area 4 |
|---|---|---|---|---|
| Sediment Pool (aerated) | 95% | 90% | 85% | 80% |
| Detention Pool (aerated) | 5% | 10% | 15% | 20% |

e. Single-purpose floodwater retarding structure with 100-year life where top of riser or low-stage port in a two-stage principal spillway is at the 50-year elevation.

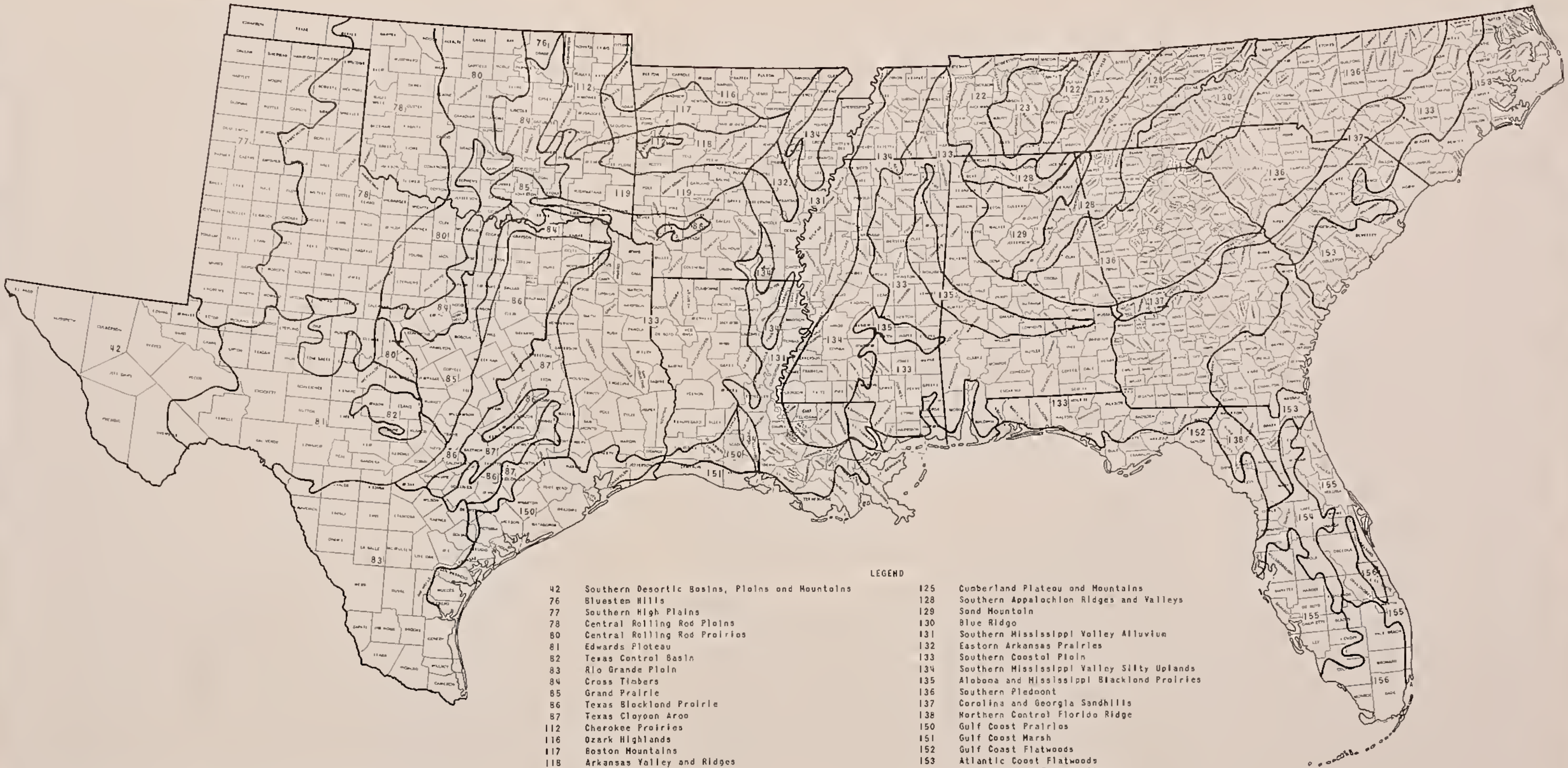
| | Area 1 | Area 2 | Area 3 | Area 4 |
|---|---|---|---|---|
| 1st 50 yrs.-Sediment Pool (submerged)- | 95% | 85% | 75% | 65% |
| Detention Pool (aerated) | 5% | 15% | 25% | 35% |
| 2nd 50 yrs.-Sediment Storage(submerged) | 90% | 80% | 70% | 60% |
| Detention Pool (aerated) | 10% | 20% | 30% | 40% |

f. Single-purpose floodwater retarding structures with 50- to 100-year life where State laws limit water storage in sediment pools.

Planning staff geologist should use his best judgment or consult with the EWP Unit Geologist (Watersheds) in allocating sediment storage to the several pools.

2. The geologist will complete Form SCS-309 (Figure 5) for all proposed watershed reservoirs. Indicate on this form the structure purpose.

This form will be furnished to the watershed work plan staff engineer for his use in preparing the preliminary design for the structure.



LEGEND

| | | | |
|---|---|---|---|
| 42 | Southern Desertic Basins, Plains and Mountains | 125 | Cumberland Plateau and Mountains |
| 76 | Bluestem Hills | 128 | Southern Appalachian Ridges and Valleys |
| 77 | Southern High Plains | 129 | Sand Mountain |
| 78 | Central Rolling Red Plains | 130 | Blue Ridge |
| 80 | Central Rolling Red Prairies | 131 | Southern Mississippi Valley Alluvium |
| 81 | Edwards Plateau | 132 | Eastern Arkansas Prairies |
| 82 | Texas Central Basin | 133 | Southern Coastal Plain |
| 83 | Rio Grande Plain | 134 | Southern Mississippi Valley Silty Uplands |
| 84 | Cross Timbers | 135 | Alabama and Mississippi Blackland Prairies |
| 85 | Grand Prairie | 136 | Southern Piedmont |
| 86 | Texas Blackland Prairie | 137 | Carolina and Georgia Sandhills |
| 87 | Texas Claypan Area | 138 | Northern Central Florida Ridge |
| 112 | Cherokee Prairies | 150 | Gulf Coast Prairies |
| 116 | Ozark Highlands | 151 | Gulf Coast Marsh |
| 117 | Boston Mountains | 152 | Gulf Coast Flatwoods |
| 118 | Arkansas Valley and Ridges | 153 | Atlantic Coast Flatwoods |
| 119 | Ouachita Mountains | 154 | South Central Florida Ridge |
| 122 | Highland Rim and Pennyroyal | 155 | Southern Florida Flatwoods |
| 123 | Nashville Basin | 156 | Florida Everglades and Associated Areas |

From: Map of "Land Resource Regions and Major Land Resource Areas of the United States" (48 conterminous states) dated January 1963; attachment to Soils Memorandum SCS-49, Dec. 19, 1962.

From: Map of "Land Resource Regions and Major Land Resource Areas of the United States" (48 conterminous states) dated January 1963; attachment to Soils Memorandum SCS-49, Dec. 19, 1962.


FIGURE 4

LAND RESOURCE AREAS
STATES SERVED BY SOUTH
REGIONAL TECHNICAL SERVICE CENTER

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FORT WORTH, TEXAS

SCALE IN MILES

0 100 200 300

Revised 10-64 4-R-18903

Base from U. S. Department of Commerce, Bureau of the Census-1960

Revised 10-64 Base 4-R-10919

4-19870

SCS-309
Rev. 10-67

Figure 5
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE



# RESERVOIR SEDIMENTATION DESIGN SUMMARY

WATERSHED Elm Creek SITE NO. 10 DRAINAGE AREA 1.50 Sq. Mi. 960 Acres

LOCATION Hill County STATE Any PURPOSE Flood Prevention

DATA COMPUTED BY Sam Spade TITLE Geologist DATE October 1967

## SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

| | | PRESENT CONDITIONS | | | FUTURE (AFTER CONS. TREATMENT) | | | |
|---|---|---|---|---|---|---|---|---|
| | | ACRES | SOIL LOSS (TONS/AC) | TOTAL (TONS) | ACRES | SOIL LOSS (TONS/AC) | TOTAL (TONS) | |
| SHEET EROSION | CULTIVATED LAND | 800 | 20.17 | 16,136 | 800 | 16.23 | 12,984 | |
| | IDLE LAND | | | | | | | |
| | PASTURE - RANGE | 160 | 4.03 | 644 | 160 | 2.01 | 322 | |
| | WOODLAND | | | | | | | |
| | OTHER | | | | | | | |
| | | DELIVERY RATIO (%) | | TONS DELIVERED | DELIVERY RATIO (%) | | TONS DELIVERED | |
| SHEET EROSION - TOTAL | | 49 | 15,780 | 8,222 | 49 | 13,306 | 6,520 | |
| GULLY EROSION | | 80 | 48 | 38 | 80 | 36 | 29 | |
| STREAMBANK EROSION | | 90 | 37 | 33 | 90 | 28 | 25 | |
| STREAMBED EROSION | | | | | | | | |
| FLOODPLAIN SCOUR | | | | | | | | |
| OTHER (ROADSIDE ETC.) | | | | | | | | |
| | | | TOTAL | 8,293 | | TOTAL | 6,574 | 1/ |

1/ The 6574 tons sediment yield reflects 100% Land Treatment. An adjustment of 45% for effective land treatment installed during the installation period is made -

(8293 - 6574) 45% = 774
8293 - 774 = 7519 tons

## DEPOSITION

| TEXTURE INCOMING SEDIMENT | | |
|---|---|---|
| % CLAY | % SILT | % COARSE |
| 40 | 45 | 15 |
| VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT. | | |
| SUBMERGED | 50 | |
| AERATED | 82 | |

| SEDIMENT DELIVERED TO SITE (TONS/YR) | | TRAP EFFICIENCY (%) | ANNUAL DEPOSITION (TONS) | DESIGN PERIOD (YRS) | PERIOD DEPOSITION (TONS) | DESIGN DEPOSITION (TONS) |
|---|---|---|---|---|---|---|
| PRESENT | 8,293 | 90 | 7,464 | 10 | 71,150 2/ | |
| FUTURE | 7,519 | 90 | 6,767 | 40 | 270,680 | 341,830 |
| FUTURE | 7,519 | 90 | 6,767 | 50 | 338,350 | 338,350 |
| | | | TOTALS | 100 | | 680,180 |

2/ Based on average of present and future deposits - 7115 tons

## SEDIMENT STORAGE REQUIREMENTS

| PERIOD (YRS) | CONDITION OF SEDIMENT | % OF TOTAL | DEPOSITION (TONS) | VOLUME WEIGHT TONS/AC.FT. | STORAGE REQUIRED ACRE-FEET | STORAGE REQUIRED WATERSHED INCHES | STORAGE ALLOCATION (ACRE FEET) SEDIMENT POOL | RETARDING POOL | OTHER |
|---|---|---|---|---|---|---|---|---|---|
| 1st 50 | SUBMERGED | 95 | 324,739 | 1,089 | 298 | 3.73 | 298 | | - |
| | AERATED | 5 | 17,091 | 1,786 | 10 | .13 | 7 | 3 3/ | - |
| 2nd 50 | SUBMERGED | 90 | 304,515 | 1,089 | 280 | 3.50 | 280 | | - |
| | AERATED | 10 | 33,835 | 1,786 | 19 | .24 | - | 19 | - |
| 100 | | TOTALS | 680,180 | | 607 | 7.60 | 585 | 22 | - |

3/ Geologist will use judgment in estimating the distribution of aerated sediment during the 1st 50 years.

4-19870

# CHAPTER X

## ESTIMATING EFFECT OF LAND TREATMENT ON EROSION RATES

When computing soil loss from sheet erosion it is important that the work plan staff geologist use the most accurate and realistic estimate possible of the effect of land treatment measures on reducing this loss. The following is a step-by-step procedure for making this study:

1. Select sample areas to be used in the study.
   a. The drainage areas of 25 percent of the proposed floodwater retarding structures will suffice for sampling a watershed.
   b. A 10 percent grid sample of homogeneous areas is satisfactory. The grid system should be selected at random with alternate grids of 640 acres or 320 acres selected for mapping. Smaller samples may be more practical.
   c. The sample area used, whether a or b above, should represent all conditions in the watershed that affect soil loss by sheet erosion.
2. Soil survey data to be used.
   a. Standard soil surveys should be used where available.
   b. Partial coverage by standard soil surveys can be supplemented by other, older types of surveys.
   c. If no soil surveys are available or coverage is inadequate, a request should be made, through the State office, for a soil scientist to provide a good reconnaissance soil survey of the sample areas.

3. Soil survey data should be transferred to an overlay map of each sample area. This will include soil type and percent slope.
4. Field mapping on the latest available aerial photograph of each sample area by the work plan staff geologist will include:
   a. Land use.
   b. Crops grown during year in which work plan is developed.
   c. Tabulation of effective land treatment practices.
   d. Average present cover condition on pasture and woodland.
   e. Slope length of each soil-slope group.
   f. General observation of effectiveness of existing land treatment measures. (Stubble mulching, crop residue use, contouring, etc.)
5. Transfer all supplemental field mapping (item 4 above) to the overlay map (item 3 above). The data on the overlay map should then be measured with a planimeter or grid and tabulated in detail.
6. All data tabulated in item 5 above should be summarized on a form similar to table 5, Watershed Sheet Erosion Data. Land capability units should be obtained from the appropriate State Land Use and Treatment Alternative Land Resource Guide.
7. The present status of land treatment in the watershed and projected future land treatment should be obtained from the work unit conservationist(s) involved. These land treatment data should be tabulated for the entire watershed as follows:

a. Total conservation needs.

b. Land treatment practices installed to date.

c. Land treatment practices to be applied during the installation period of the project.

d. An estimate of land use in the watershed provided by the work unit conservationist.

8. Analyze land treatment data (item 7 above) to determine the weighted percent of the total conservation needs applied to date, and the weighted percent of these total needs which will be applied during the installation period of the project.

9. Using the appropriate Land Capability Guide, the geologist should consult with the work unit conservationist to determine which alternative conservation treatment is most applicable in the watershed if 100 percent land treatment is installed.

10. Using these projected future land treatment data, the geologist will compute soil loss from sheet erosion and summarize on the same form (see item 6 above).

11. With the soil loss computed for present conditions (with existing land treatment) and for future conditions (with projected 100 percent land treatment), the geologist should use the weighted percent of land treatment to be applied during the installation period (item 8 above) and adjust the future soil loss accordingly before entering the soil loss data on Form SCS-309.

12. Sediment storage requirements should be adjusted to allow for applied land treatment to become fully effective. For example,

if the project has a 5-year installation period, a mean average between present and future soil-loss rates should be used for 8 to 10 years and future soil-loss rates should be used for the remaining 90 to 92 years (40 to 42 years if the project life is 50 years). The use of this average soil-loss figure for the first 8- to 10-year period will allow for the gradual improvement of watershed conditions.

# CHAPTER XI

## INVESTIGATIONS TO DETERMINE THE EXTENT OF FLOOD PLAIN PHYSICAL LAND DAMAGE

Most of the flood plain investigations, including overbank deposition, flood plain scour, swamping, and associated damages, can be made on the cross sections. If these cross sections are located to afford proper distribution and average widths, they will provide a good basis for the flood plain sedimentation survey.

The geologist or his assistants will make traverses along the cross sections and record all conditions regarding channels, scoured areas, overbank deposits, alluvial fans, and other features. Note should be made on erosion conditions of the valley slopes and terraces. Auger borings should be made at intervals of about 200 feet if modern sediment deposits have occurred. Locations of borings, sediment thicknesses and depth of scour, and depth to the original soil may be plotted on a copy of the valley cross section. Field notes on depth, texture, and composition of the sediment can be used in estimating damages. Channel conditions should be described, including information on channel deposition or erosion, and streambank sections which show modern deposits, old soils, underlying alluvium, and bedrock.

If the flood plain contains a continuous widespread sediment deposit, evaluations of conditions in any one segment can be made on the basis of the data obtained on the bounding ranges. If approximate figures on sediment volume in the valley are desired, an estimate can be made by

multiplying the area of the segment by the average thickness found on the two bounding ranges. Features such as flood plain splays, alluvial fans, and widely scattered flood plain deposits should be investigated separately and their areas, average depths, and types of sediment determined to evaluate damages in each locality.

1. Overbank deposition.

The following is presented as a guide to identification of the chief types of accelerated valley deposits, including channel deposits.

| Type of Deposit | Definition |
|---|---|
| Channel Fill | Relatively coarse sediment partly or completely filling formerly normal channels. |
| Vertical Accretion | Deposits from widespread overflows. Coarser and thicker on natural levees; finer and thinner away from channel. |
| Flood Plain Splays | Relatively coarse, fan-shaped deposits from overflows, channeled through low places in natural levees. |
| Colluvial | Material chiefly from sheet erosion mixed with talus on edges of flood plains at the foot of valley slopes. |
| Alluvial Fans | Relatively coarse, fan-shaped deposits at debouchure of tributaries on main flood plain. |
| Lateral Accretion | Channel deposits on insides of bends accompanying channel migration. |

Channel Lag — Coarse material deposited in streambed by selective deposition.

On flood plains where modern deposition is widespread the natural levees, which usually are dominant features, may be several feet thick. From the channel and natural levees the deposits of vertical accretion generally taper gradually in thickness toward the edges of the flood plain. Where sedimentation from tributaries and valley slopes has been rapid, alluvial fans and colluvial deposits overlie the edges of the flood plain deposit. If accelerated deposition in the main channel has been excessive, the channel may have become completely filled and its elevation raised above the base of the natural levees. In this case, subsequent flood flows generally follow an entirely different course. In some valleys modern sedimentation has caused substantial damage to the flood plain but has not formed a continuous valley-wide deposit. Under these conditions the study of damaged areas involves identification and interpretation of a series of separate deposits.

The following list summarizes the principal types of damage caused by accelerated sedimentation in valleys and channels:

Burial of fertile alluvial soils by less fertile sediment.

Filling of channels, causing increased flood heights and frequencies.

Impairment of drainage, with an accompanying rise in water table and increase in swampy areas.

Damage to water supplies due to increased turbidity.

Damages to growing crops and pastures.

Damages to roads, bridges, and railroads.

Filling of drainage and irrigation ditches with sediment deposits.

Urban damages by sedimentation and increased flood heights.

Damages to recreational facilities.

Accessory scour damage.

Valley trenching, and streambank erosion damages.

Identification of deposits formed by modern accelerated deposition is based primarily upon proper distinction between modern sediment and the buried original flood plain soil. Since the characteristics of both the sediment and buried soils vary widely in different localities, these relationships must be investigated when beginning a flood plain damage study. The following is a list of important criteria on which distinction can be based:

Texture:

Sediment - usually coarser with greater range in texture.

Buried Soil - usually finer with more uniformity in texture.

Color:

Sediment - generally lighter and may vary with texture.

Buried Soil - generally darker and more uniform.

Compaction:

Sediment - less compact and less cohesive.

Buried Soil - more compact and cohesive.

Distinctive Minerals:

Sediment - grains of micas, gypsum, feldspar, calcite, or other easily weathered minerals.

Buried Soil - very few grains of easily weathered minerals - some firm concretions. Abundance of clay minerals.

Buried Evidence of Cultural Activity:

Sediment - buried boards, tools, bricks, fences, and other manmade objects; also partly buried tree trunks.

Buried Soil - surface of old soil also may have evidence of cultural activity.

Stratification and Water Table Relationships:

Sediment - usually has distinct stratification with crossbedding and lenticular beds; a perched water table supported by the old soil may be in the sediment deposit.

Buried Soil - little stratification; overlies older normal alluvium.

It is possible for a soil to be improved by relatively more fertile sediment, such as a silt deposit over a very sandy soil. Where sheet erosion is still occurring primarily in surface soil, the redeposition of this material on bottomlands often

is a benefit. However, in many watersheds sheet erosion has reached the point where the eroded material is chiefly subsoil, and in addition much infertile material is being contributed by gullies, streambanks, and roadsides. It is, therefore, becoming increasingly difficult to find examples of the improvement of bottomland soils by the products of erosion.

It should be borne in mind that the amount of damage caused by sediment depends on several factors; the texture of the sediment, the depth of deposit, and the rate of deposition. As an example, consider two areas of silt loam bottomland soil which have received sand deposition. One has had a deposit of 1.5 feet, accumulated at the rate of 0.1 foot annually for 15 years. It has been possible to mix the sand with the surface (plow depth) soil each year; therefore, although the productive capacity of the soil has diminished from that of the original capacity, it is still in production. The other area may have received a deposit of only 1 foot of sand, but this has occurred in 1 or 2 years. With plows commonly in use it is impossible to mix this sand with the underlying soil. The damage in this instance is much higher and the area may have to be retired from cultivation. In some instances it is possible, by deep plowing, to restore the productive capacity of the area, but the cost may be prohibitive.

The geologist should estimate the percent damage caused by overbank deposition, usually to the nearest 10 percent. See table 8, page XI-8. This is done by determining the depth and texture of the sediment and estimating the loss in productive capacity, or by comparing the crops with crops on similar undamaged flood plain land. In some instances it may be desirable to list the damages by the original undamaged potential land use in order to provide the economist a better basis for the conversion of the physical data into monetary damage estimates.

These data should be recorded on a form similar to the sample form in figure 6. In summarizing the overbank sediment deposition it may be necessary to summarize the damage by reaches. This can be accomplished by using the sample form as a summary sheet. The lineal feet of each category of damage found on each individual cross section is assumed to occur one-half the distance above and one-half the distance below the cross section. This distance, in feet, multiplied by the lineal damage distance in feet, equals the total square feet of damage. Separate categories of damage are computed in this manner at each cross section and converted to acres. The acreages of all damage categories are then determined for each reach, and the acreages for all reaches are added together to obtain the total damage for the flood plain.

Table 8

OVERBANK SEDIMENTATION DAMAGE 1/

| DEPTH (Ft.) | PERCENT DAMAGE BY TEXTURE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coarse Sand | Sand | Medium Sand | Fine Sand | Sandy Silt | Clayey Sand | Silty Sand | Clayey Silt | Silty Clay | Clay |
| 0.0-0.5 | 30 | 20 | 10 | 5 | 0 | 0 | 5 | 0 | 5 | 10 |
| 0.5-1.0 | 40 | 30 | 20 | 10 | 5 | 5 | 10 | 0 | 5 | 10 |
| 1.0-1.5 | 50 | 40 | 30 | 20 | 10 | 10 | 20 | 5 | 10 | 15 |
| 1.5-2.0 | 60 | 50 | 40 | 30 | 20 | 20 | 30 | 10 | 15 | 20 |
| 2.0-3.0 | 70 | 60 | 50 | 40 | 30 | 30 | 40 | 15 | 20 | 25 |
| 3.0-4.0 | 80 | 70 | 60 | 50 | 40 | 40 | 50 | 20 | 25 | 30 |
| 4.0 + | 90 | 80 | 70 | 60 | 50 | 50 | 60 | 25 | 30 | 40 |

1/ These percentages should be adjusted for each watershed as the need arises.

2. Swamping

Swamping is any impairment of drainage of bottomland or colluvial soils by sediment deposits. It may be caused by the filling of stream channels with the products of accelerated erosion, which raises the water table on the bottomlands, or formation of natural levees by modern sediment deposits, which prevent proper surface drainage. Deposition of clay on bottomland soils causes "puddling," reduces permeability, and prevents internal drainage.

These various types of swamping damage, or impairment in drainage, are measured in conjunction with the flood plain survey of overbank deposition and related damages by boring along ranges. The percent damage to the productive capacity of the land is estimated by comparing the crops on land which has been swamped by sediment deposits with those on land which has not. Whether the flood plain is unusually wet or dry at the time of survey also should be considered.

The chief difficulty in measuring swamping damage is the determination of whether the land in question has always been swampy, or whether it has become wet in recent times because of accelerated erosion and sedimentation. Historical records may throw light on this question. Long-time residents also may remember the original condition of the land. Dead standing timber usually is positive proof that the land has become swamped in recent times. In any case, in order to properly assess the damage by swamping, the boring survey must be supplemented by

other information. In summarizing the damage the same procedure is used as in the case of overbank deposition.

3. Flood plain scour

Two types of flood plain scour have caused damages in alluvial valleys where accelerated erosion has occurred: (1) channel-type scour; and (2) sheet scour. Scour channels range from broad, gently sloping linear depressions, which have little effect on fertility or farming operations, to sharply cut channels from which much soil has been removed and which cannot be crossed by farm machinery. Sheet scour is the flood plain equivalent of upland sheet erosion. When estimated in terms of reduction in fertility and crop yield, the damages resulting from flood plain scour may range from 10 to 90 percent. See table 9, page XI-12. The chief damage from sheet scour is removal of alluvial soil, thus reducing fertility.

Numerous surveys of valleys where flood plain scour has caused substantial damages have shown that the scouring action usually is very irregular in distribution and occurrence. When a channel which has carried concentrated floodwaters becomes clogged with sediment, logs or other debris, subsequent overflows may carve new channels on other parts of the flood plain. The abandoned flood channel later may become filled or partly filled with sediment, thus restoring a part of its former fertility and improving its topography.

In determining the extent and degree of scour the percent damage and lineal distance of each type along the cross section should be measured. Computations of the acreage of damage are made in the same manner as for overbank deposition. A form similar to the sample form in figure 7 may be used for this purpose.

4. Streambank erosion

This is the lateral erosion which occurs on streambanks. The caving and eroding of the banks result in loss of land, as well as contributing additional sediment to the stream system. Estimates of annual land loss by this process may be made by comparison of old and present-day aerial photographs or by measuring the segments of actively eroding banks and estimating the average annual lateral erosion in feet or tenths of feet.

5. Valley trenching

This is the deepening and headward cutting of a channel. It is, in effect, flood plain or colluvial area gullying and may result in the lowering of water tables of adjacent bottomlands, as well as providing an additional source of sediment to a stream system. Serious trenching also can cause active erosion of drainage ditches and tributary channels by increasing their gradients, thus causing them to cut deeper and migrate headward. The main items of damage are land loss, land depreciation, and sediment production which can be computed by estimating the average annual area voided by headcutting and widening.

Table 9

FLOOD PLAIN SCOUR DAMAGE 1/

CHANNEL SCOUR 2/

| Depth (Feet) | Width (Feet) | | | |
|---|---|---|---|---|
| | 0-25 | 25-50 | 50-100 | 100-200 |
| 0.0 - 0.5 | 15% | 10% | 5% | 0% |
| 0.5 - 1.0 | 20% | 15% | 10% | 5% |
| 1.0 - 1.5 | 25% | 20% | 15% | 10% |
| 1.5 - 2.0 | 30% | 25% | 20% | 15% |
| 2.0 - 3.0 | 40% | 30% | 25% | 20% |
| 3.0 - 4.0 | 50% | 40% | 30% | 25% |
| 4.0 + | 60% | 50% | 35% | 30% |

SHEET SCOUR 3/

| Depth (Feet) | Width (200 Feet +) | |
|---|---|---|
| 0.0 - 0.5 | 10% | |
| 0.6 - 1.0 | 20% | |
| 1.0 - 2.0 | 30% | |
| 2.0 - 3.0 | 40% | |

1/ These tables should be adjusted for each watershed to allow for localized differences between areas. Percent damages should be summarized to the nearest ten percent.

2/ As scour channels become wider, damage decreases due to (1) less difficulty in farming operations and (2) the tendency for broad scour channels to recover by refilling with sediment.

3/ Due consideration should be given to the remaining depth of the alluvial soil profile.

4-19870

SAMPLE FORM

FIGURE 6

UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service

FLOOD PLAIN DAMAGES
(OVERBANK DEPOSITION)

WATERSHED____________ LAND RESOURCE AREA____________ COMPUTED BY________

| REACH | BOUNDING CROSS SECTIONS | TEXTURE OF DEPOSIT | DEPTH (FT.) | WIDTH (FT.) | LENGTH (FT.) | ACRES DAMAGE | PERCENT DAMAGE | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

SAMPLE FORM

FIGURE 7

UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service

FLOOD PLAIN DAMAGES
(SCOUR OR VALLEY TRENCHING)

WATERSHED__________ LAND RESOURCE AREA__________ COMPUTED BY__________

| REACH | BOUNDING CROSS SECTIONS | NUMBER OF SCOUR CHANNELS OR AREA OF SHEET SCOUR | DEPTH (FT.) | WIDTH (FT.) | LENGTH (FT.) | ANNUAL RATE OF EROSION (AC.-FT.) | ACRES DAMAGE | PERCENT DAMAGE | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
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# CHAPTER XII

## DETERMINATION OF OTHER APPLICABLE TYPES OF SEDIMENT DAMAGES

1. Reservoir damage

Reservoirs are investigated for three chief purposes: (1) to evaluate reservoirs and large ponds as water sources, (2) to determine their rates of capacity loss by sedimentation and the relationship of sediment production rates to climatic and watershed conditions, and (3) to evaluate effects of reservoirs on downstream developments.

All reservoirs and large ponds should be located and their history investigated to determine the feasibility of a sedimentation survey. (If a dam has been breached, or substantial amounts of sediment removed, it is unlikely that reliable measurements of capacity loss or indications of upstream sediment contribution rates could be determined.) With this information at hand, surveys may be made to obtain data on rates of capacity loss and rates of sediment production which are typical of the area.

a. Reservoir sedimentation surveys

Detailed procedures for making these surveys are contained in Technical Release No. 22, October 9, 1964.

b. Evaluation of capacity loss and its effects

The first step in evaluating reservoir sedimentation damage is to compile a list of reservoirs in the watershed, including data on capacity, size of drainage area, use, date of construction, and cost of construction. Information to

supplement that on file may be obtained from the E&WP Unit files, Corps of Engineers, State Conservation Commissions, State water organizations, county engineers, and personal inspection.

Using the original storage capacity of the reservoir, the original cost per acre-foot adjusted to current prices may be determined. If the annual rate of sedimentation is estimated from existing reservoir survey data, the annual damage can be computed. This method of computation of damage is known as the straight-line depreciation method. By this method the same evaluation is placed upon storage in various parts of a reservoir, although it is known that multipurpose reservoirs may have pools at various levels designated for sediment storage, power, water supply, flood control, or other purposes. This basis usually is used by the economist in calculating damages and benefits.

If replacement of the reservoir at another location is not possible, it is necessary to estimate costs of such expedients as dredging, or raising the dam, and converting it to cost per acre-foot of storage regained. If no remedial measures are possible, the economist can evaluate the loss of the services.

In the case of reservoirs for power production the damage by sedimentation may be evaluated by the loss of generating capacity. Most power reservoirs depend upon power generation from two sources--reserve storage and run-of-the-river flow.

The latter is independent of sedimentation and is most reliable during wet periods. Reserve storage gradually diminishes with sedimentation until the carryover storage of the power pool is depleted and power generation is limited to river flow. The damages resulting from the loss of power-generating capacity can be evaluated by the economist.

After a power reservoir is filled with sediment other damages, especially to the power plant machinery, may result even though some power still can be produced. Silt, sand, or gravel may be transported through the reservoir, after it is filled with sediment, and cause damage to turbines and other equipment. In this way, excessive wear and maintenance costs may result. These costs can be evaluated.

2. Excess cost of removing sediment from water supplies

Cities and industries which derive their water from surface sources, whether stream or reservoir, may have high expenses for removing the sediment from the water. A part of this expense may be considered a damage, since it is partly preventable. Low water dams have disproportionally small capacity-watershed ratios and are subject to alternate scour and fill, and the effects of sedimentation on their storage capacity generally are not evaluated. However, the expense of removing sediment from the water supply still must be evaluated. Some larger impounding reservoirs, which have more favorable runoff-capacity ratios, also have turbidity sufficient to require abnormally high filtration costs.

For a watershed survey the important aspects of water use, especially surface water, should be determined. This includes municipal, irrigation and industrial use, the quantities of water used, and costs of filtration. In evaluating the effects of suspended sediment upon costs of filtration, only the cost of sediment removal should be included. These are alum treatment, increased frequency and costs of flushing filters, and removing sediment from other equipment and pipelines. Other normal phases of water treatment, such as chlorination, carbon treatment, and pumping, should not be included.

3. Navigable harbor sedimentation

When harbors become shallow because of sediment deposits large vessels can use them only during high water periods, or not at all. In order to preserve the effectiveness of these channels, dredging is required.

The annual cost of this dredging is the damage in this case. Costs of all dredging done by the Corps of Engineers may be obtained from their annual reports, which are available in any Corps of Engineers' office. Local interests usually do some dredging in addition to that done by the Corps of Engineers. In converting this annual cost to long-term annual cost, it should be borne in mind that dredging costs have risen more rapidly than excavation costs in recent years.

Other types of damage also may be present. It may be necessary to load ships lightly in order to get them through channels partially filled with sediment. The ships may become stuck or suffer damage because of sediment deposits or they may require extra tugs to get through. All these damages can be evaluated on an average annual basis.

If the harbor involved is situated downstream from the watershed being studied, it is necessary to estimate what proportion of the total harmful sediment is coming from this watershed. This depends upon the size of the watershed in relation to other watersheds contributing sediment to the harbor. It also depends upon the rates of sediment production from the watershed in question and from the other watersheds contributing to the problem. These rates of sediment production can be derived from existing suspended sediment and reservoir sedimentation survey records. Only that portion of the annual cost of downstream dredging chargeable to the watershed under study may be used as a damage.

4. Damage to transportation facilities

Sediment deposits damage highways and railways by collecting in ditches and culverts and on the roadways, and by filling channels beneath bridges. These deposits must be removed to maintain normal traffic, and the damage may be calculated in terms of annual maintenance costs. In some cases the bulk of the sediment deposits requires construction of new and higher bridges or fills. The costs of such items are properly attributed to sedimentation and should be reported on an annual basis. For county and State roads, these damages can be converted into annual costs per mile.

5. Sedimentation in irrigation and drainage ditches

Ditches excavated for irrigation and drainage commonly sustain some loss in capacity or effectiveness by sedimentation from year to year. Sediment causing partial filling of such channels may be derived from erosion along the banks or from outside sources, but in any case the

damages can be evaluated in terms of annual cost of reexcavation to maintain normal capacity.

6. Evaluation of recreational losses

Although damages to recreational facilities in many cases are indefinite and difficult to evaluate, some estimates of such damages can be made. Some specific examples are as follows: decline of fishing because of increased turbidity or deposition of sediment in and around a lake; deposition of mud on sandy beaches; decline of property values for residences around a lake; and shoaling of water, preventing or hampering the use of boats. Such damages are sometimes evaluated in terms of money spent for the various facilities or numbers of people attracted to a lake.

7. Damage to property

After most floods deposits of sediment are found on streets and in homes, factories, machinery, sewers, wells, and other places where they cause damage. The cost of removing this sediment is considered the damage.

If these damages are present in significant amounts they may be obtained from city officials, factory representatives, or other agencies. Frequently the Corps of Engineers may have records of this type of damage.

Usually it is desirable to have records of this type for a period of years for cities, industries, and farms. The figures then can be reduced to an average annual damage during the period.

# CHAPTER XIII

## CHANNEL STABILITY INVESTIGATIONS DURING WORK PLAN DEVELOPMENT

The installation of a watershed project, with the resulting change in flow regimen and sediment yield, may affect the stability of channels downstream from watershed works of improvement. For this reason the planning staff geologist should make a field reconnaissance early in the planning stage, with other planning staff technicians, to determine if, in their judgment, there may be a stability problem. All channels should be considered whether or not improvement is proposed. If there is any indication of instability, the following field investigations should be made:

1. Field Investigation

   Many problems in the planning and preliminary design of channel improvements are easy to recognize, but some are not. For this reason it is necessary to make a field reconnaissance of the channel improvement reach, or channel of questionable stability, early in the planning stage.

   The field reconnaissance party should include an engineer or hydrologist, a geologist, a survey party chief, and others as needed. The reconnaissance should start at the upper end of the channel and progress downstream to the outlet end, or to where the project ends. The channel should be divided into selected reaches, the length of which should be based on similarity of the cross section, slope, and soil material. Where these elements of a channel are nearly constant for

relatively long distances the reaches should not exceed 2 miles in length.

The reaches should be identified either numerically or alphabetically, and so marked on the most recent 8-inch aerial photograph available. Also, the existing alignment of the main channel, tributaries, and side drains should be identified. This is necessary in those instances where, due to topography and cover, alignments are difficult to locate with any confidence. Also, the alignment may have changed since the photographs were taken. Fences, property lines and ownership, works of man, etc. which may affect the planning and preliminary design should be located. This may be done later, after the field surveys have been completed.

A written description of each reach should follow the reconnaissance. This description should include, but not be limited to, the following:

a. Geologic description of area.

b. Land use.

c. Existing condition of channel (aggrading, degrading, apparently stable).

d. If instability is noted, discuss possible causes.

e. Estimate of channel roughness (Manning's "n").

f. Present channel alignment (sinuosity).

g. Evidence of recent flooding (high water marks, etc.).

h. Critical hydraulic control points (bridges, roads, rock outcrops, etc.).

i. Classify base flow (continuous or intermittent).

It is recommended that the engineer and geologist flag the cross sections. The watercourse also should be flagged. In arid areas, where indistinct watercourses are encountered, a topographic survey may be necessary to determine the true watercourse. The survey party chief should be included on the field party so that he will understand fully the scope of the survey required.

2. Identification of Specific Problems

During the field investigation problems and questions may arise that do not have an immediate answer or solution. Identify and record each of these problems and questions for further intensive study.

Consult with the appropriate specialists in other fields for assistance and recommendations. After the problems have been isolated, the next step is to develop an outline for the investigation and preliminary design of the problem channel reach or reaches.

3. Outline for Investigation and Preliminary Design

a. Field investigations

(1) Survey cross sections and profiles

(a) Cross sections should be surveyed at reasonably close intervals, not to exceed 1,000 feet.

Stationing should comply with Engineering Memorandum SCS-39 Revised, dated January 27, 1960.

(b) Profiles should follow the watercourse (thalweg).

(2) Select representative soil sample locations in each reach

(3) Collect samples for laboratory analysis

(a) Noncohesive soils

(i) Samples should be obtained to a depth of 5 feet below proposed grade.

(ii) Use bulldozer or back-hoe.

(iii) Where correlation of individual beds or lenses is not possible, a weighted average grain size should be determined for each pit. A disturbed sample should be obtained from each different horizon or lens in the pit. Then by scale drawing of the pit wall, measure the area each horizon or lens occupies and use this weighting to determine the grain size distribution.

(iv) Where bedding is relatively uniform, select a disturbed sample from each horizon.

(v) Where the grain size exceeds 3 inches, all material remaining on the No. 4

sieve should be separated and weighed in the field. These weights should be provided to the Materials Testing Section in order for the entire sample to be reflected in the analysis.

(b) Cohesive soils

(i) Samples should be obtained to a depth of 2 to 4 feet below proposed grade.

(ii) Use core drill or power auger.

(iii) Obtain representative disturbed samples of each horizon.

(iv) In some cases, representative undisturbed samples may be required.

b. Office computations

(1) Analyze laboratory results.

(a) Correlate sample results.

(b) Plot the grain size distribution graphs.

(2) Geologist and engineer (or hydrologist) should determine:

(a) Maximum allowable tractive force for each reach. (See page XIII-13.)

(b) Maximum allowable velocities for each reach. (See page XIII-16.)

(3) Obtain the preliminary channel design from the engineer.

(a) Select design flood.

(b) Determine drainage areas.

(c) Determine design discharge for each reach.

(d) Develop water surface profiles for existing channel.

(e) Design channel.

(f) Develop water surface profiles for improved channel.

(g) Compute actual tractive force and/or mean velocity.

(i) Use depth of flow as determined from water surface profiles.

(h) Compare computed values of tractive force and/or velocity with the allowable values for these parameters. If the computed values are greater than allowable for the type of soil material encountered, a scouring or degrading channel can be predicted, in which case it will be necessary to make adjustments in the preliminary design to bring the actual values of tractive force and velocity within acceptable limits. If the computed values are less than the allowable, an analysis of the type and amount of sediment transported by the stream channel will be necessary to determine whether the channel will aggrade by filling with sediment.

(i) The volume of bed material expected to be transported through a particular channel reach, within a given period of time, can be estimated by use of one of the following bedload transport equations:

<u>Meyer-Peter Equation (For coarse sands through coarse gravels)</u>

$$q_s = (Aq^{2/3}S - B\ d_m)^{3/2}$$

$$\text{or } q_s = (39.25\ q^{2/3}\ S - 9.95\ d_m)^{3/2}$$

<u>Schoklitsch Equation (For medium sands through fine gravels)</u>

$$q_s = A\ \frac{S^{3/2}}{d^{1/2}}\ (q - q_c)$$

$$\text{or } q_s = 86.7\ \frac{S^{3/2}}{d^{1/2}}\ (q - 0.00532\ \frac{d}{S^{4/3}})$$

<u>Haywood Equation (Fine through medium sands)</u>

$$q_s = \frac{(q^{2/3}S - Ad^{4/3})^{3/2}}{Bd^{1/3}}$$

$$\text{or } q_s = \frac{(q^{2/3}S - 1.20d^{4/3})^{3/2}}{0.117d^{1/3}}$$

In the above equations

A and B are constants with differing values for the various formulae.

$q_s$ = pounds per second, bedload transport per foot of average channel width

$q$ = discharge (cfs) per foot of average channel width

$s$ = hydraulic gradient (ft./ft.)

$d$ or $d_m$ = representative diameter of bed material 1/

$q_c$ = critical discharge - the discharge (per foot of average channel width) at which bed material starts to move

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1/ $d$ or $d_m$ values are expressed in the following units of measure depending on the equation used:

Meyer-Peter - $d_{35}$ in feet

Schoklitsch - $d_{50}$ in inches

Haywood - $d_{35}$ in feet

To compute the volume of sediment transported as bedload through a channel reach the geologist should:

1. Divide the reach into segments and determine the incremental drainage area for each segment in square miles.
2. Compute the soil loss from all sources for each incremental drainage area and apply the appropriate delivery ratio to each channel reach.

3. Determine the median grain size of bed material from representative channel bed samples.
4. Estimate sediment transport characteristics, starting with the farthest upstream reach, as follows:

The transport capacity of the streamflow contributed by uncontrolled runoff areas should be computed separately from the transport capacity of outflow from floodwater retarding structures. These two transport capacities should be introduced at the uppermost reach of the stream and progressively brought downstream. The hydrologist should provide the volume of flow by constructing a hydrograph for each reach. By measuring the volume under the hydrograph, and dividing it by the time base, the average "Q" (discharge) can be derived for use in the bedload equation. The volume of flow from the uncontrolled area should be brought through the reaches first to predict aggradation or degradation as a result of storm runoff. The outflow from retarding structures is then considered to determine the effect of prolonged flow on the aggrading or degrading channel.

Compare the transport capacity for streamflow in each reach with that portion of the incoming

sediment estimated to be bedload. When computing incoming sediment load, an estimate must be made of the percent of sediment yield which will be transported as bedload and that which will be carried as suspended load. This can be accomplished by obtaining representative upland soil samples (from all sediment sources) and comparing their average grain size distribution with that of existing bed material samples.

If the estimated volume of bedload exceeds the transport capacity of the design flow, aggradation will occur. The transport capacity is subtracted from the incoming bedload to determine the amount of aggradation and the portion of the load transported into the next lower reach. The bedload transported to the next reach is then compared with the transport capacity in that reach, and so on down through each reach to the mouth of the watershed.

If the transport capacity exceeds the incoming bedload, degradation can be expected. If degradation is predicted, the amount of sediment degraded from one reach is equal to the transport capacity of that reach, less the incoming bedload.

By using this approach, aggradation and/or degradation can be estimated reach by reach for any

stream that carries a significant bedload.

The effects of land treatment and structural measures on erosion and sediment yield should be used to predict bedload transport after project installation.

Soil samples should be obtained to represent all sediment sources in a watershed. For example, sheet erosion samples should come from the top few inches of representative soil series, while gully and streambank samples should be composites and should be collected from channel banks and beds.

A form, similar to that shown on the following page, can be used in compiling and tabulating bedload transport information. The following example is provided to illustrate the procedure:

*SAMPLE FORM*

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

## COMPUTATION OF BEDLOAD TRANSPORT BASED ON SEDIMENT YIELD

WATERSHED Any Creek  STREAM Camp Creek  COMPUTED BY Sam Spade, Geologist  DATE July 1968

BEDLOAD TRANSPORT – EQUATION USED: Schoklitsch  SEDIMENT YIELD

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Channel Section Or Reach | Avg. Dis-chg. Plus Re-lease Q CFS | Bot-tom Width $B_o$ (feet) | Discharge Per Foot Of Chan. Width q CFS | Average Slope ft./ft. | Medi-an Grain Size mm 3/ | Transport Capacity lbs/sec/ ft. of width qs | Duration of Flow dd Sec. | Transport Capacity lbs. | | Incremental Drainage Area Sq. Mi. | Gross Erosion Tons/ Sq.Mi. | Deli-very Ratio % | Total Sediment Yield Tons | Total Bedload Available For Trans. Tons | Transport Capacity Tons | + Aggrade - Degrade Release Plus Storm Runoff Tons | + Aggrade - Degrade Release Flows Only Tons |
| Solution | (From Preliminary Design) | | | | From Sample | From Bedload Eq. | From Design | Columns 3 X 7 X 8 | | From Data | Compute | From Graph | Columns 10X11X12 | Col. 13 X % Avail. | Column 9÷2000 | | |
| 1 1/ | 231 | 20 | 11.55 | .0016 | 1.14 | 0.2691 | 68,436 | 368,185 | | 3.36 | 2822 | 46 | 4362 | 436 | 184 | +252 | |
| 2/ | 88 | 20 | 4.40 | .0016 | 1.14 | 0.0818 | 303,084 | 497,058 | | | | | | | 249 | | +3 |
| 2 1/ | 381 | 32 | 11.91 | .0016 | 1.14 | 0.2784 | 84,096 | 748,118 | | 5.21 | 2822 | 41 | 6028 | 603 | 375 | +412 | |
| 2/ | 88 | 32 | 2.75 | .0016 | 1.14 | 0.0386 | 287,424 | 355,026 | | | | | | | 177 | | +484 |
| 3 1/ | 445 | 44 | 10.11 | .0016 | 1.14 | 0.2314 | 88,632 | 900,856 | | 2.06 | 2822 | 49 | 2848 | 284 | 451 | +208 | |
| 2/ | 100 | 44 | 2.27 | .0016 | 1.14 | 0.0261 | 282,888 | 323,624 | | | | | | | 162 | | +223 |
| 4 1/ | 473 | 66 | 7.17 | .0006 | 1.14 | 0.0147 | 93,060 | 90,287 | | 1.41 | 2822 | 51 | 2029 | 203 | 45 | +609 | |
| 2/ | 100 | 66 | 1.52 | .0006 | 1.14 | - | 278,460 | - | | | | | | | 0 | | +771 |
| 5 1/ | 534 | 70 | 7.63 | .0014 | 1.14 | 0.1308 | 106,884 | 980,126 | | 4.03 | 2822 | 42 | 4777 | 478 | 490 | + 33 | |
| 2/ | 100 | 70 | 1.43 | .0014 | 1.14 | - | 264,636 | - | | | | | | | 0 | | + 33 |

1/ - Discharge includes release flows.
2/ - Release flows only - after storm hydrograph dissipated.
3/ - Units of mm are used because nomographs and tables developed for the solution of the Schoklitsch equation have been adjusted to reflect mm instead of inches.

Derivation of Values in Cols. 16 & 17

Col. 16 - Storm Runoff Plus Release Flows

| | |
|---|---|
| 436-184 | = 252 |
| 184 + 603 - 375 | = 412 |
| 375 + 284 - 451 | = 208 |
| 451 + 203 - 45 | = 609 |
| 45 + 478 - 490 | = 33 |

Col. 17 - Release Flows Only

| | |
|---|---|
| 252-249 | = 3 |
| 249 + 412 - 177 | = 484 |
| 177 + 208 - 162 | = 223 |
| 162 + 609 - 0 | = 771 |
| 0 + 33 - 0 | = 33 |

# ALLOWABLE TRACTIVE FORCE

1. Introduction

The purposes of this section are: (1) to briefly define "tractive force," (2) to show the results of investigations correlating critical or allowable tractive force with various properties of cohesive and noncohesive soils, and (3) to recommend a range (or limits) of allowable tractive force values for use in the design of stable channels.

2. Tractive Force

Tractive force is the force (or shear) exerted by moving water on the boundary of a channel and is given by the equation,

$$T = Wds$$

Where, $T$ = tractive force in lbs./ft.$^2$

$W$ = unit weight of water (62.4 lbs./ft.$^3$)

$d$ = depth of water in feet

$s$ = slope of energy gradient in ft./ft.

3. Tractive Force Vs. Physical Properties of Soils

a. General

There are three classes of alluvial material through which channels flow. These three classes are: (1) coarse, noncohesive material, (2) fine, noncohesive material, and (3) cohesive material. The results of studies and investigations correlating tractive force to the physical properties of soils are grouped accordingly.

b. Coarse, Noncohesive Materials

Figure 8 shows the results of studies made by E. W. Lane[1/] on the San Luis Valley Canals, Colorado. Lane found the upper limit to be 0.5 times the $D_{75}$ size measured in inches. He recommends for design the lower limit of 0.4 times the $D_{75}$ size measured in inches.

c. Fine, Noncohesive Materials

Figure 9 gives three curves which were developed by E. W. Lane[1/] and are based on the median grain size ($D_{50}$) and the relative fine sediment load carried by the water. Curve No. 1, high content of fine sediment, refers to streams that contain a load of 2 percent or more of silt and clay sizes on an average of two or three times a year, but that carries a low content of sand. Curve No. 2, low content of fine sediment, refers to streams that contain a content of silt and clay sizes reaching 0.2 percent concentration two or three times a year on the average and having a very low content of sand. Curve No. 3 is for clear water. Lane states that his curves are not applicable where much sand is carried; however, he does not set the limits for the allowable sand content.

d. Cohesive Materials

Figure 10 gives two curves developed by Dunn[2/] and Smerdon. Curve No. 1 was developed by Dunn from flume studies made on cohesive soils from Colorado, Wyoming, and Nebraska.

Curve No. 2 was developed by Dr. Ernest Smerdon, Texas A&M University, from unpublished studies made on cohesive soils having a void ratio (e) of 0.3 to 0.6 representative of a compact bed.

4. Recommendations

Recommended limits of allowable tractive force for design purposes are indicated on figures 8, 9, and 10. A good knowledge of channel stability principles and problems are a prerequisite to the use of the tractive force method of designing channels. The maximum allowable tractive force used in design should be based on the least stable soil horizon found within the channel reach under consideration.

5. References

1/ Lane, E. W., "Design of Stable Channels," Transactions ASCE, Volume 120, 1955, p. 1234.

2/ Dunn, Irwin S., "Tractive Resistance of Cohesive Channels," Journal of the Soil Mechanics and Foundations Division, ASCE, June 1959.

# MAXIMUM ALLOWABLE VELOCITY

1. Introduction

The purposes of this section are: (1) to define maximum allowable velocity, (2) to show the results of various investigations correlating allowable velocity with soil type and soil grain size, and (3) to recommend allowable velocities for use in design of stable channels.

2. Maximum Allowable Velocity

The maximum allowable velocity is defined as that mean velocity which will not objectionably scour the bed or banks of a channel.

3. Investigations of Velocity Vs. Soil Type

a. Soils - PI Above 10

Figure 11 was developed from data by Fortier and Scobey[1/], Lane[2/], and by investigation in the USSR[3/]. Use of this figure will require laboratory soil tests to determine the plasticity index and the liquid limit. A plot of PI and LL will classify the soil type and give the allowable velocity for clear water and colloidal load.

b. Soils - PI Below 10

Figure 12 gives Hjulstrom's[4/] erosion curve. Investigations made by U. S. Bureau of Reclamation[5/] and Rubey[6/] correlate very good with Hjulstrom's curve. Use of this figure will require a laboratory analysis of grain size.

4. Recommendation

Recommended allowable velocity for preliminary design purposes is indicated on figures 11 and 12. These are for straight channels. There are corrections to be applied for depth of flow and channel alignment as indicated by Lane[3/]; however, these two corrections usually cancel each other. The maximum allowable velocity should be based on the least stable soil horizon found within the channel reach under consideration.

5. References


1/ Fortier, S. and Scobey, F. C., "Permissible Canal Velocities," Transactions ASCE, Volume 89, 1926.

2/ Lane, E. W., "Design of Stable Channels," Transactions ASCE, Volume 120, 1955.

3/ Bureau of the Methodology of the Hydro-Energo Plan, "Standards for Permissible Non-Eroding Velocities," Moscow, USSR, May 1936. Quoted by Lane in reference 2.

4/ Hjulstrom, F., "Curves for Erosion and Deposition of a Uniform Material," Uppsala University, Sweden, Geological Institute Bulletin XXV, 1935.

5/ Jarecki, E. A., "Design of Stable Channels with Tractive Forces and Competent Bottom Velocity," Sedimentation Section, Bureau of Reclamation, Denver, Colorado. March 1960.

6/ Rubey, William W., "The Force Required to Move Particles on a Stream Bed," U. S. Geological Survey, Professional Paper 189-E, 1938.

COARSE, NONCOHESIVE MATERIALS

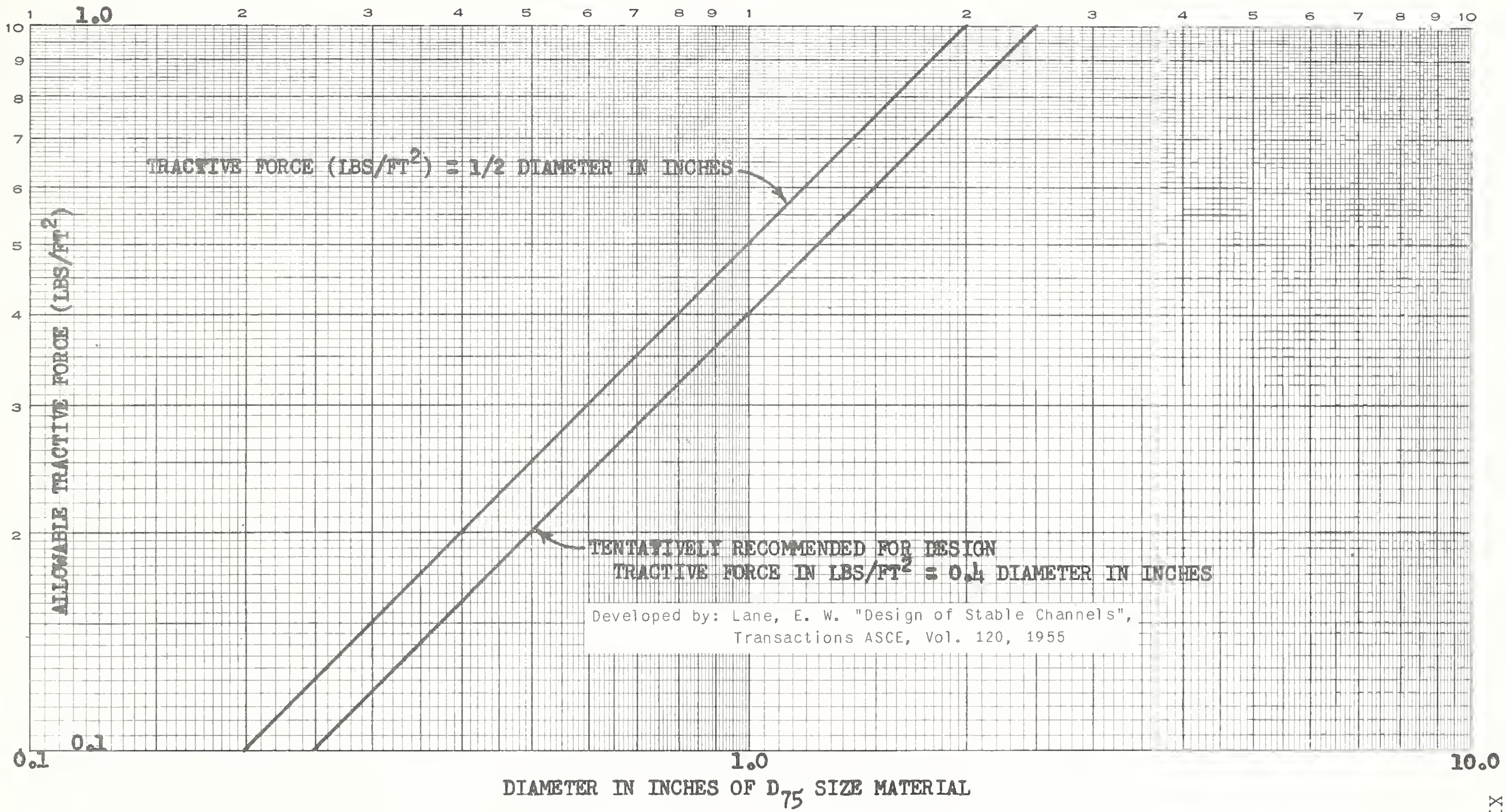
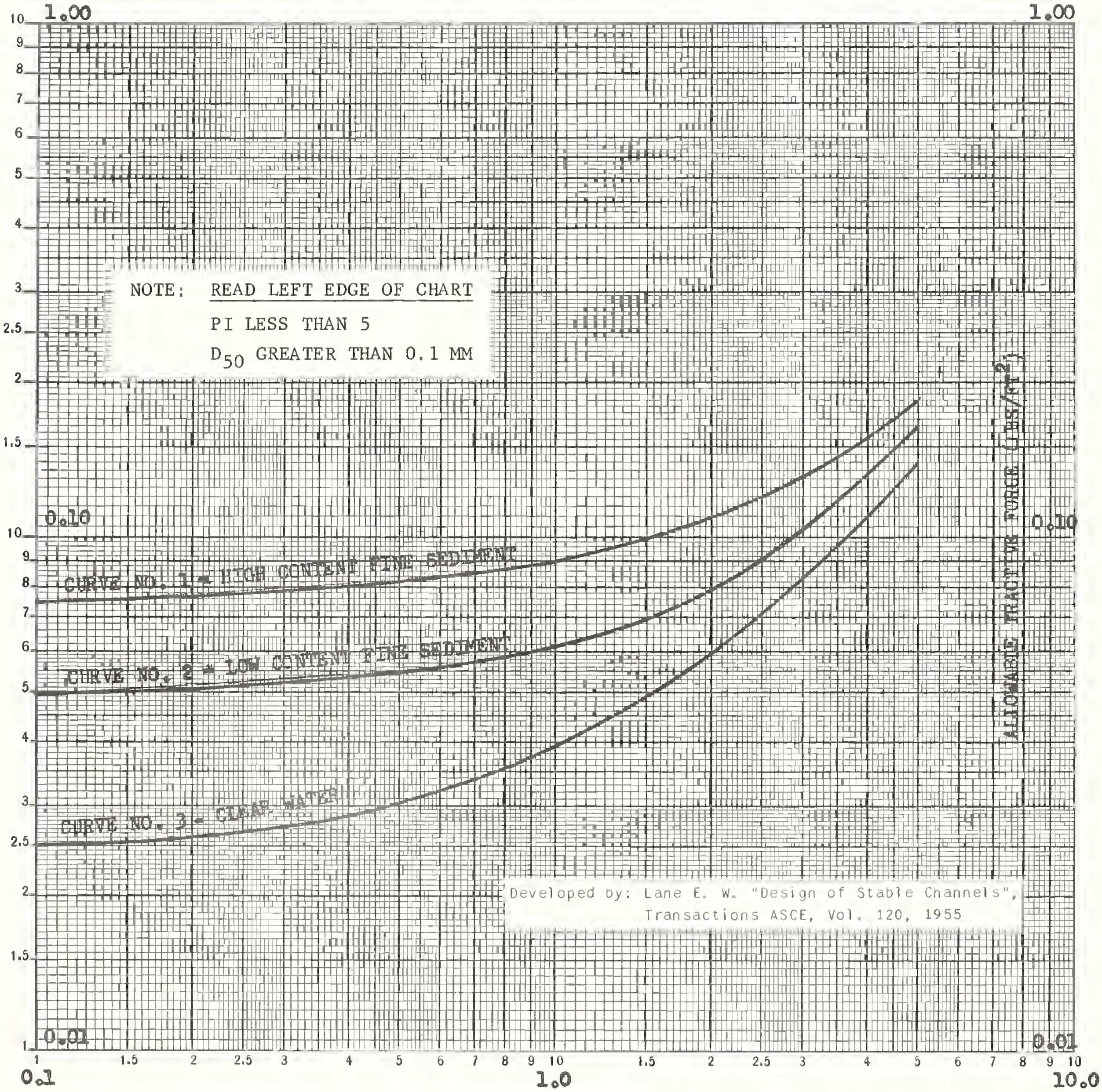



FIGURE 8

## FINE, NONCOHESIVE MATERIALS




MEDIAN GRAIN SIZE ($D_{50}$) IN MM

FIGURE 9

## COHESIVE MATERIALS

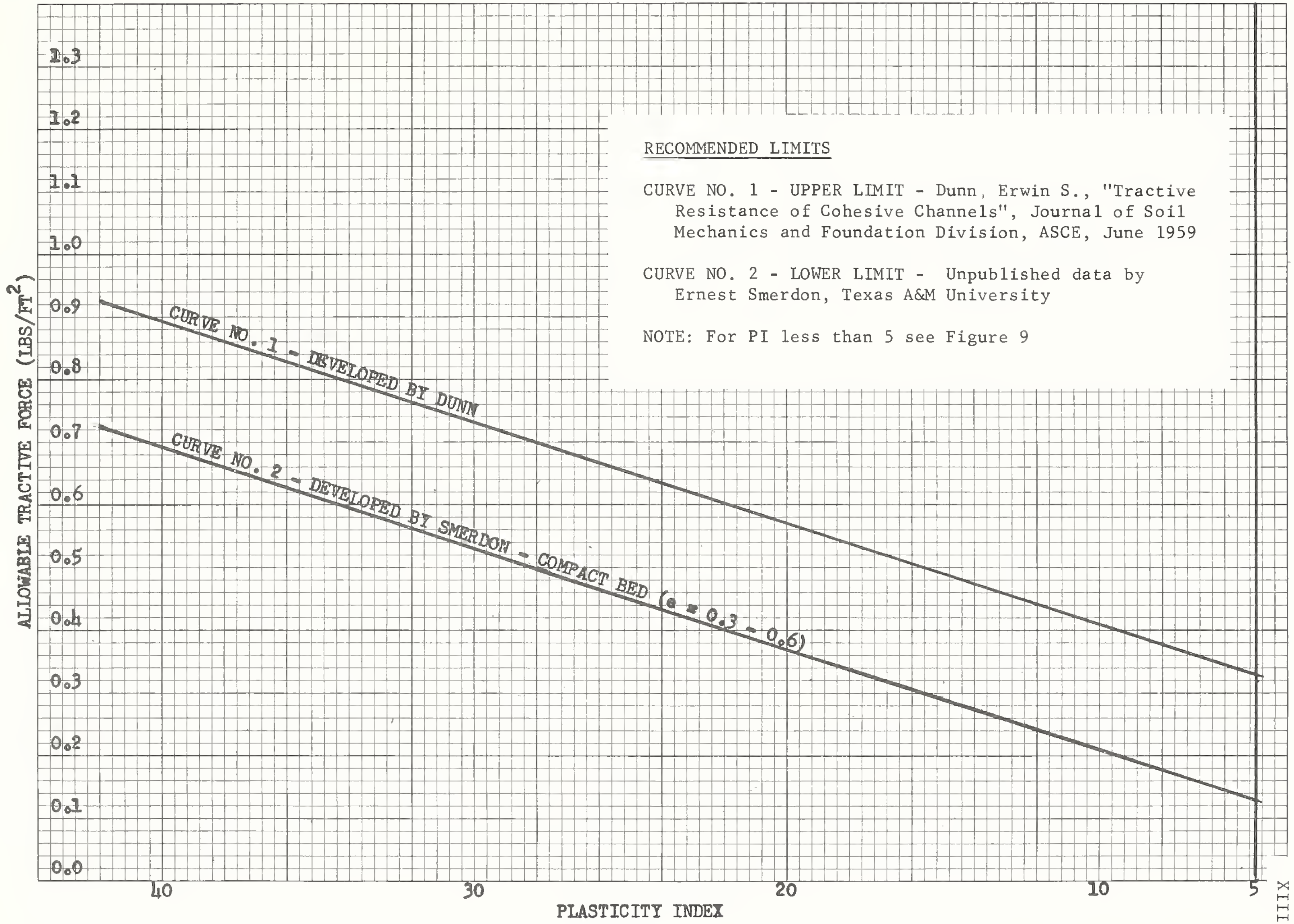
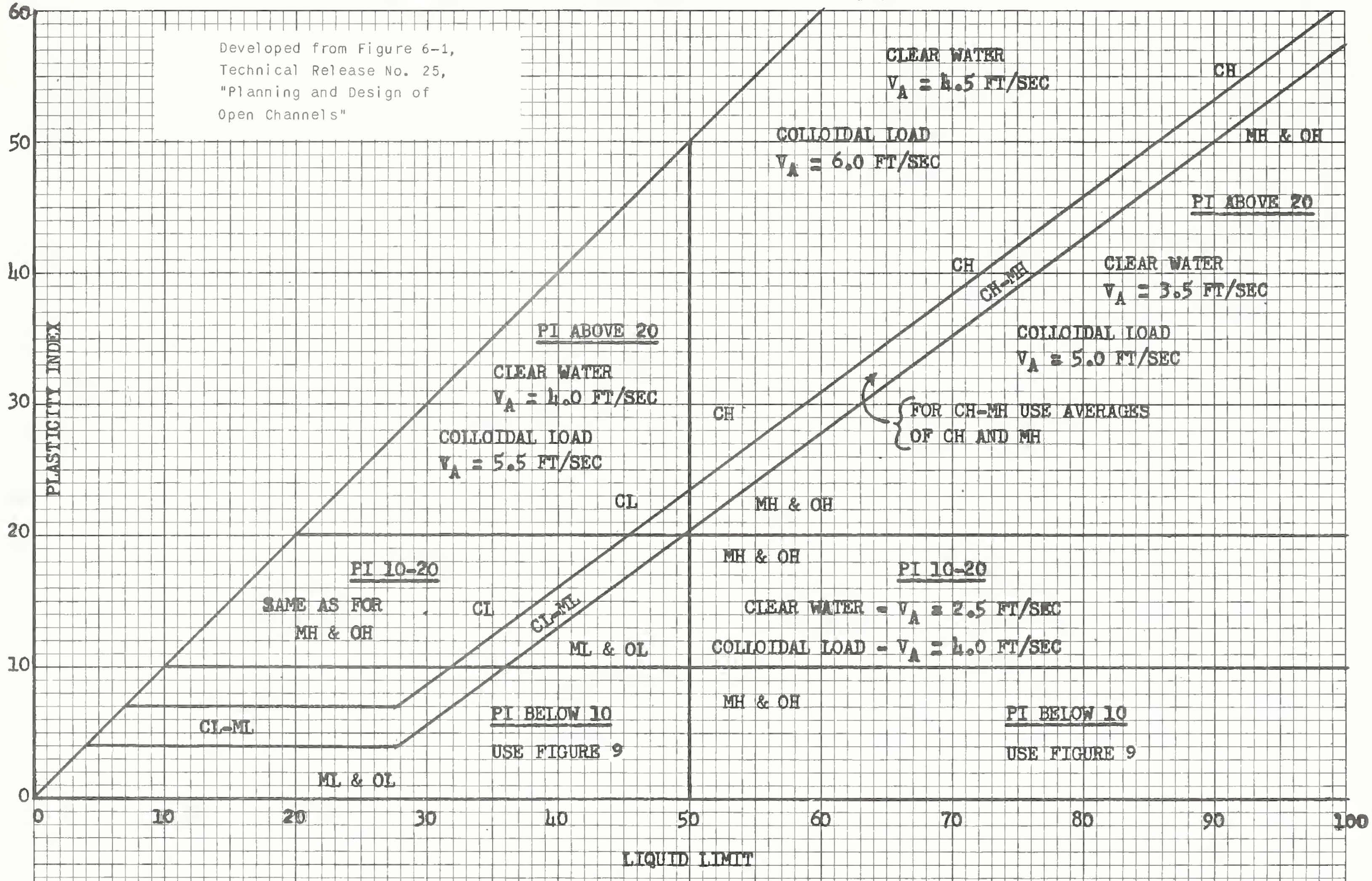



FIGURE 10

ALLOWABLE VELOCITY BASED ON LABORATORY SOIL CLASSIFICATION




PLASTICITY CHART FOR LABORATORY CLASSIFICATION OF ~~FINE~~-GRAINED SOILS

FIGURE 11

# ALLOWABLE VELOCITY FOR SOILS HAVING A PLASTICITY INDEX BELOW 10

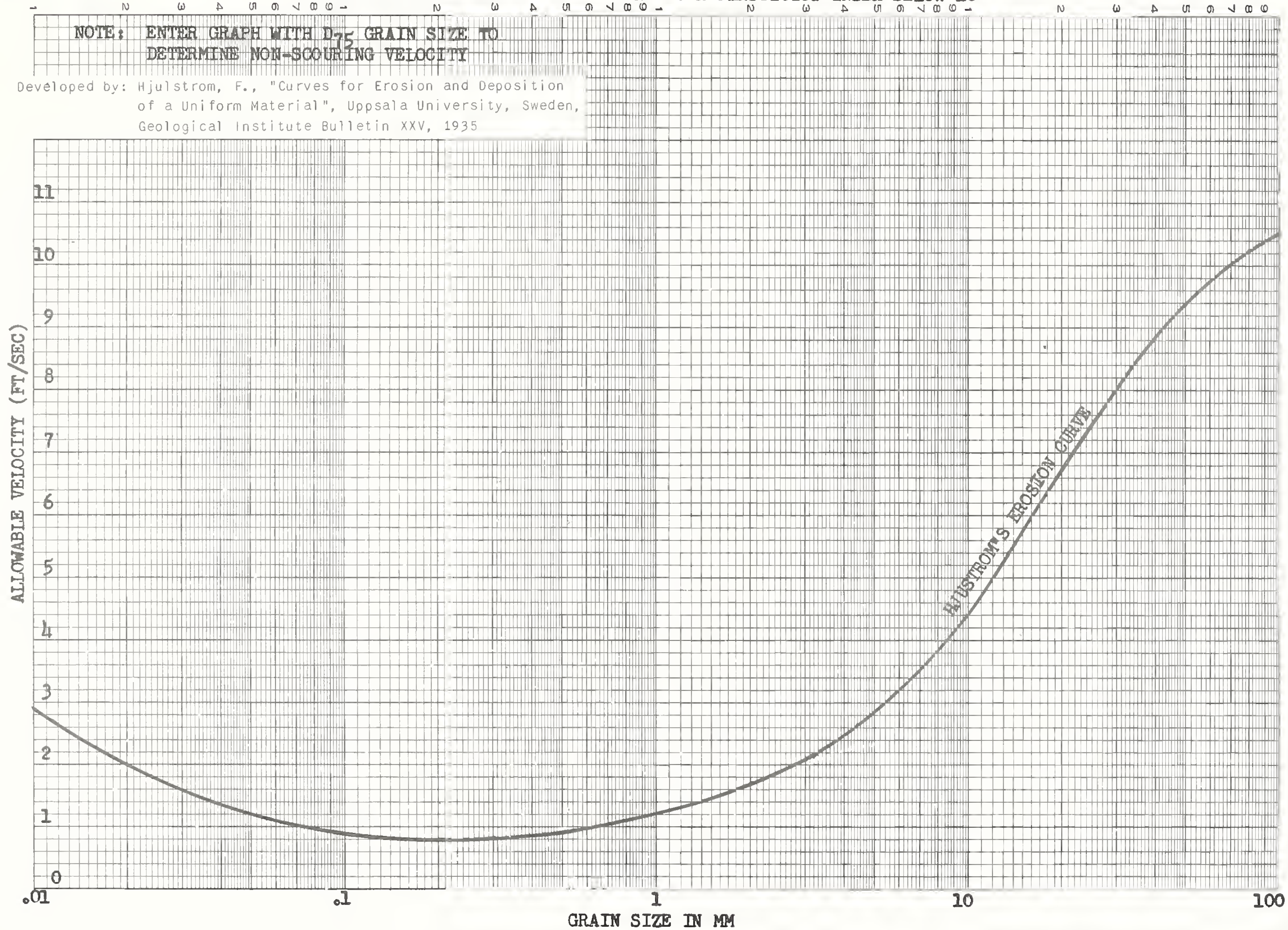



FIGURE 12

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4-19870

Rev. 10-65 4-L-18444-2 of 2

# CHAPTER XIV

## SEDIMENT SOURCE - SEDIMENT DAMAGE RELATIONSHIPS

Sources of damaging sediment may include all or part of the following:

| | |
|---|---|
| Sheet erosion | Roadside erosion |
| Gully erosion | Valley trenching |
| Streambank erosion | Flood plain scour |

Total erosion from sheet, gully, and roadside erosion usually can be obtained by expanding the erosion rates determined from the detailed sediment source studies above selected floodwater retarding structures, providing such areas are representative of erosion conditions. Total erosion from the other sources, such as valley trenching, flood plain scour, and streambank erosion, usually is obtained by using the data gathered during the flood plain damage survey.

The amount of annual erosion from each sediment source can be converted to a percentage of the total erosion. It is then possible to determine the relative importance of each type of erosion, or sediment source, for specific types of damage. Some types of damage are caused largely by one type of sediment. The location of the damage area, whether in the upper or lower reaches of the stream system, and the texture of sediment delivered to the damage area also influence the relative importance of any sediment source.

Some types of sediment are transported only short distances from their original source before being redeposited. Some types of erosion, such as flood plain scour, do not occur in headwater areas. It is, therefore, necessary for the geologist to estimate, for each type of sediment damage, the relative importance of the various sediment sources.

4-19870

In the following example, the percentages of each sediment source have been determined as follows in a watershed:

| Sediment Source | Percent of Total |
|---|---|
| Sheet Erosion | 81 |
| Gully Erosion | 8 |
| Streambank Erosion | 3 |
| Flood Plain Scour | 2 |
| Road Erosion | 6 |
| Total | 100 |

The table below then can be developed to show the relationship of each sediment source to various types of damage which occur in the watershed.

| Type of Damage | Sheet Erosion | Gully Erosion | Streambank Erosion | Flood Plain Scour | Road Erosion | Total |
|---|---|---|---|---|---|---|
| Overbank Deposition | 68 | 15 | 10 | 1 | 6 | 100 |
| Swamping | 40 | 30 | 20 | 0 | 0 | 100 |
| Farm Ponds | 90 | 8 | 0 | 0 | 2 | 100 |
| Major Reservoir | 25 | 20 | 25 | 10 | 5 | 100 |

By referring to the above, the effect of erosion reduction in terms of benefits can be estimated. For example, 68 percent of the overbank deposition damage is caused by sheet erosion. Assuming that sheet erosion can be reduced 22 percent by land treatment the reduction in overbank deposition damage from this source will be reduced 15 percent (22.0 x 68.0).

Reductions in overbank deposition damage brought about by land treatment and structural measures can be computed as shown in the following table:

REDUCTIONS IN OVERBANK DEPOSITION

| (1) Source of Sediment % | (2) Sediment Deposit. % | (3) Erosion Reduction by Land Treatment % | (4) Damage Reduction by Land Treatment % | (5) Damage Remaining After Land Treatment % | (6) Erosion Reduction by F.W.R. Struct. % | (7) Damage Reduction by F.W.R. Struct. % | (8) Damage Remaining % |
|---|---|---|---|---|---|---|---|
| Solution | | | Col. 2x3 | Col. 2-4 | Controlled area | Col. 5x6 | Col. 5-7 |
| Sheet | 68.0 | 22.0 | 15.0 | 53.0 | 38.0 | 20.1 | 32.9 |
| Stream Bank | 10.0 | 17.0 | 2.0 | 8.0 | 38.0 | 3.0 | 5.0 |
| Gully | 15.0 | 17.0 | 3.0 | 13.0 | 38.0 | 5.0 | 8.0 |
| Scour | 1.0 | 1.0 | 0.1 | 0.9 | 66.0 | 0.5 | 0.4 |
| Roadside | 6.0 | 17.0 | 1.0 | 5.0 | 38.0 | 2.0 | 3.0 |

Total remaining after land treatment = 79.9

Total remaining after Project 49.3

Reduction due to Land Treatment only = 100% - 79.9 = 20%

Reduction due to total project = 100% - 49.3 = 50%

4-19870

# CHAPTER XV

## SUMMARIZE PHYSICAL DAMAGES

Make a summary table of all land damages. Show total annual acre damages by percent categories. Also show estimated percent recovery and number of years to recover from sediment and scour damages. Furnish the economist with these data for his monetary evaluation. Also furnish the economist with the estimated percent reduction in these damages by both land treatment and structural measures, based on available technical data on the effect of the program on annual sediment production.

# CHAPTER XVI

## PREPARATION OF PROBLEM LOCATION MAP

Prepare a problem location map showing areas of significant flood plain damages, critical sediment source areas and the floodwater and sediment damage area (flood plain). If desired, each symbol for sediment damages (+) and scour (s) may be used to represent 10, or any specified number, of acres of damage.

4-19870

# CHAPTER XVII

## PREPARATION OF WORK PLAN NARRATIVE (PARTS APPLICABLE TO SEDIMENTATION AND GEOLOGY)

Prepare narrative and tabular information dealing with sedimentation and related subjects for inclusion in the work plan.

In writing narrative sections pertaining to the physical nature of the watershed and other sections dealing with sedimentation or geology, use land resource area rather than physiographic area names.

4-19870

# CHAPTER XVIII

## SUBSTANTIATING DATA TO ACCOMPANY WATERSHED WORK PLAN FOR TECHNICAL REVIEW

1. Overbank deposition damage.

   Submit a brief description of methods used in estimating damages such as "Valley Section Method" or "Sample Area Mapping Method." For each category of damage (percent) list the average depth and texture of the sediment. Also list the percent recoverability assigned to each category of damage and the number of years estimated for recovery to occur.

2. Flood plain scour damage.

   Submit a brief description of methods used in estimating damages such as "Valley Section Method" or "Sample Area Mapping Method." For each category of damage (percent) list the average width and depth of the scour channels or areas affected by sheet scour. Also the percent recovery and years to recover as for sediment damage.

3. Sediment yield studies.

   a. Floodwater retarding structures.

      Submit complete sets of computations, including summary (SCS-309) forms for <u>all</u> sites where detailed sediment rates were computed. Send a completed SCS-309 for each estimated rate and a short explanation of basis for estimate. Also list each site in the watershed, showing: drainage area (square miles), sediment storage (watershed inches), sediment distribution between pools.

b. For entire watershed (where applicable).

Submit computations used to estimate net sediment yield from watershed, including delivery rate used for each sediment source.

4. Submit all computations and explanation of methods used to estimate reduction in sediment and scour damage (1) due to land treatment only and (2) with the complete program.

5. Submit all computations and explanation of methods used in the selection and treatment of critical sediment source areas, including (1) land treatment measures, (2) land stabilization measures, and (3) any other special treatment planned for critical sediment source areas.

6. Submit all computations and explanation of methods used in determining channel stability. Include such data as: bedload transport analysis; tractive force analysis.

7. Submit geologic sketch map of watershed, with reference to sources, such as geologic reports, books, etc.

4-19870

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5. "Factors Influencing Sediment Delivery Ratios in the Blackland Prairie Land Resource Area" - E&WP Unit, Fort Worth, Texas, August 1962.
6. "A Suggested Interim Guide for the Planning and Preliminary Design of Stable Channels" - E&WP Unit, Fort Worth, Texas, November 1963.
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12. Technical Release No. 22 - "Reservoir Sedimentation Surveys" - SCS, Washington, D. C., August 1965.

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14. "Sediment Source Areas, Delivery Ratios and Influencing Morphological Factors" - International Association Hydraulics Commission of Land Erosion Pub. 59, pp. 202-213, 1962, by John W. Roehl.

6597